S. 13.

U. S. DEPARTMENT OF AGRICULTURE.

FIELD OPERATIONS OF THE DIVISION OF SOILS,

1900.

[SECOND REPORT.]

BY

MILTON WHITNEY, Chief.

WITH ACCOMPANYING PAPERS BY

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(No. 8.)

A JOINT RESOLUTION providing for the printing annually of the Rep
of the Division of Soils, Department of Agricultur

Resolved by the Senate and House of Representatives of t
America in Congress assembled, That there be printed sevent
of the Report on Field Operations of the Division of Soils, D
culture, for nineteen hundred, of which three thousand copies
of the Senate, six thousand copies for the use of the House
and eight thousand copies for the use of the Department of Ag
annually hereafter a similar report shall be prepared and pri
be the same as for the report herein provided.

Approved, February 23, 1901.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF SOILS,
Washington, D. C., March 21, 1901.

SIR: I have the honor to transmit herewith the manuscript report, with accompanying illustrations and maps, of the Field Operations of the Division of Soils in 1900, the publication of which is authorized by joint resolution of the Fifty-sixth Congress, second session.

Respectfully,

MILTON WHITNEY,
Chief of Division.

Hon. JAMES WILSON,
Secretary of Agriculture.

LIST OF REPORTS.

CONTENTS.

ILLUSTRATIONS.

PLATES.

PENNSYLVANIA AREA.

OHIO AREA.

NORTH CAROLINA AREA.

UTAH AREA.

ARIZONA AREA.

CALIFORNIA AREA.

TEXT FIGURES.

PENNSYLVANIA AREA.

OHIO AREA.

MARYLAND AREA.

NORTH CAROLINA AREA.

UTAH AREA.

ARIZONA AREA.

CALIFORNIA AREA.

LABORATORY INVESTIGATIONS.

TOBACCO INVESTIGATIONS.

MAPS.

[In separate portfolio case accompanying this report.]

FIELD OPERATIONS OF THE DIVISION OF SOILS, 1900.

By MILTON WHITNEY, Chief.

GENERAL REVIEW OF THE WORK.

PURPOSE OF A SOIL SURVEY.

With the recent development of new agricultural areas, the extension and cheapness of transportation facilities, and the specialization and competition in the markets of the world, every possible factor influencing both the yield and quality of crops has to be considered by the producer. The great influence of the soil on the character and yield of crops has been recognized from the earliest times, but comparatively little systematic work has been done in soil-mapping, as soil chemists and physicists have not been able to work out a satisfactory basis for the field classification of soils. Nearly all of the Eastern and Southern States of our own country have supported at one time or another an agricultural survey in which the general character of the soils has been recognized and described. This information is scattered through a great number of reports on agriculture and geology, many of them dating in the early part of the nineteenth century. Many maps have been published also, representing the general distribution of soil types, but based principally upon the geologic origin of the material. Soil maps have also been made in foreign countries, notably in Russia, Germany, France, England, and Japan; but these have been based, as a rule, upon the geology of the area rather than upon the specific character of the soils. Innumerable attempts have been made to classify the soils according to the laboratory results obtained in investigations of the chemical composition or the physical texture, and combinations have been tried in which the chemical composition, physical properties, geological relations, and crop values have all been recognized.

In the inauguration of the soil-survey work in the Division of Soils it was recognized that differences of commercial value could be seen in the field from the character of the soil and from its relation to crops and vegetation; that it was quite possible to map these soil areas independently of the geology of the area or the exact chemical or physical character of the soil; that the proper course was to con-

struct maps in the field, showing the area and distribution of the soil types; to explain as fully as possible from geological considerations the origin of the soil, and to have the soil chemist and physicist study the differences in the soil types. The fact is recognized that these chemical and physical properties of the soils are so complex and difficult that it may take many years to explain them through laboratory investigation; but, pending this complete investigation, the maps themselves will be of the utmost value to the agriculturists in indicating the areas over which certain soil conditions are found to prevail. It is clearly recognized that the climate has much to do with the relation of soils to crops, and for this reason a brief statement of the climatic conditions is always given in the reports. It is also recognized that certain economic conditions, frequently local, have a controlling influence upon the relative crop values of a soil. The chief among these are the questions of ease and cost of transportation, the market conditions, and the conditions of labor and similar social conditions. These matters are brought out as clearly and as strongly as possible in the reports of the work.

Undoubtedly, the most pressing demands for a soil survey arise from a consideration of special problems. It may be for the consideration of industries which could be introduced into a section of the country where, from the increased competition and the openi up of new areas, the specialization of crops at present grown in the area, or from various social problems, the industries have languished and new industries or new methods are desired to build up the locality. A very important consideration, however, lies in the introduction and spread of new industries, in the improvement and development of the different types of tobacco, of fruit production, of truck growing, of sugar beets, and of other special crops; also in the improvement of certain soil areas by the use of fertilizers, by the introduction of underdrainage, and in the West by the protection of soils against seepage waters and alkali and the reclamation of lands already injured by these causes. The alkali problem is already well in hand. The influence of the soil upon the production of early truck and upon the production of different types of tobacco has also been pointed out in previous publications of the Division. The recent successful growing of Sumatra tobacco on a certain soil in the Connecticut Valley is a very striking instance of the possibilities growing out of the detailed soil survey in any given locality.

ORGANIZATION OF THE DIVISION.

The Division as at present organized has a soil survey for the States east of the Mississippi River and a soil survey for the States west of the Mississippi River, this separation of the work being made partly for administrative purposes and partly because the problems are somewhat different in the two sections of the country. There is a laboratory of soil physics and a laboratory of soil chemistry for con-

sidering and investigating the many problems which are referred to this Division and also for investigating the numerous problems encountered by the soil survey parties. Strong emphasis is laid upon the fact that the laboratories are to supplement and to strengthen the work of the soil survey and to investigate the many problems observed by the field parties, some of these being of local interest and others of broad general principles concerning the differences between the various types of soils and their relative crop values. There is also the line of tobacco investigations in which the special adaptation of certain soils to tobacco is being studied, with special reference to the possibilities of improving the quality of our domestic tobaccos and of introducing new varieties.

In the prosecution of the field work an effort is made, so far as possible, to correlate the soils of the different areas, that is, if essentially the same soils having the same texture and composition, so far as can be determined, and the same crop values (climatic conditions being considered) are found in different areas, they are given the same name, any local peculiarities being described in the accompanying reports. This avoids any unnecessary increase in the number of types, thus simplifying the nomenclature, and calls attention to a similarity of soils and to the possibilities of the extension of industries into new localities if climate and economic conditions permit. This is considered a distinct advantage in the work.

So far as possible, the topographic sheets of the United States Geological Survey are used as base maps for the soil work. Where these are not available reliable county maps have been used in some cases, and in one case, where no reliable maps were available, a traverse map was constructed by one of the State organizations. The maps are all published on a scale of 1 inch to the mile. On this basis a square of 10 acres represents an area one-eighth inch square on the map, and this is taken as the unit in soil mapping.

The present volume includes reports from all of the soil-survey parties of 1900. The object has been to exploit as far as possible the actual conditions prevailing in the different districts; to suggest as far as this can safely be done the possibilities of improved methods and the introduction of new crops; and to call attention to the chief problems which need further investigation or which need to be met by improved methods. In this review the writer has attempted to briefly summarize the results of the investigations, to call attention to the important factors operating to explain the present conditions, and to mention the problems which will need to be solved for the different areas. It is thought that this treatment of the subject will be more comprehensive and of more economic value than any other.

PROGRESS AND COST OF THE SOIL SURVEY.

During the season of 1900 six well-organized parties were in the field for from six to nine months each, equipped according to the

most modern methods for investigating and mapping the soils of several important agricultural districts. Four thousand four hundred and sixty square miles, or about 2,857,600 acres, have been mapped on a scale of 1 inch to the mile. The following table shows the areas which have been mapped, the rate of mapping per day, and the actual cost of the field work per square mile (including the salaries of the men while actually in the field, their subsistence expenses, and transportation within the area, but not the cost of transportation to or from the area).

Areas surveyed, rate of mapping per day, and cost per square mile.

Districts.	Area surveyed.	Rate of mapping per day.	Cost per square mile.
	Square miles.	*Square miles.*	
Lancaster County, Pa	270	3.8	$2.53
Montgomery County, Ohio	480	8.9	1.19
St. Mary County, Md	360	4.6	1.11
Calvert County, Md	218	3.5	1.91
Kent County, Md	315	6.2	.77
Raleigh to Newbern, N. C.	1,000	5.6	1.10
Sevier Valley, Utah	220	2.2	4.54
Weber County, Utah	307	5.3	2.16
Tempe, Phoenix, and Buckeye, Ariz	370	4.4	2.09
Fresno, Cal	625	4.7	2.10
Santa Ana, Cal	300	4.3	2.26
Total	4,465		

The average rate of mapping for each party was 4.4 square miles per day and the average cost was $1.97 per square mile, or three-tenths of a cent per acre.

The following table shows the progress of soil mapping to date, including the work in 1899 and 1900, compared with the area of the States and the area in farm land:

Area in farm land, improved land in farms, and area surveyed, by States.

States.	Area of State.	Area in farm land.	Improved land in farms.	Area surveyed.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Arizona	72,269,000	1,297,000	104,000	256,000
California	99,827,000	21,427,000	12,223,000	530,000
Connecticut	3,101,000	2,253,000	1,379,000	170,000
Maryland	6,310,000	4,952,000	3,413,000	812,000
Massachusetts	5,146,000	2,998,000	1,657,000	85,120
New Mexico	78,374,000	787,000	263,000	85,120
North Carolina	30,091,000	22,651,000	7,829,000	640,000
Ohio	26,086,000	23,352,000	18,339,000	307,000
Pennsylvania	28,790,000	18,364,000	13,211,000	162,000
Utah	52,602,000	1,324,000	548,000	512,000

The data regarding the area in farm lands and the improved land in farms are from the Eleventh Census, 1890, the latest data available. In the Eastern States, where there is relatively little unimproved land, the data of the unimproved land in farms will give an approximate idea of the extent of the demands there may be for soil mapping in the several States. Nearly all districts to be mapped will include some unimproved land together with the improved; but on the other hand there are many areas in mountains, forests, or arid regions where the improved land in farms bears but a small proportion to the unimproved land and where there will be no justification, at least for the present, to extend the soil mapping, as the agricultural interests are small. In the Western States much virgin land has been brought under cultivation since the Eleventh Census was taken, and the area of farm land and of improved land in farms will unquestionably increase largely and rapidly as the possibilities of irrigation are extended by the construction of reservoirs and irrigation works, so that it is impossible to measure at the present time the possible demands there will be for such work in those States.

COOPERATION WITH STATE ORGANIZATIONS.

It has been the policy of the Division, as in the past, to cooperate to the fullest extent possible with the State experiment stations, the State geological surveys, and the State boards of agriculture, to promote the interests of the work and the interests of the local institutions. Such cooperation insures a continuity and uniformity in the plans and methods of the soil work, it concentrates the experience of other localities in solving local problems in the classification of soils and the adaptation of crops, and it leaves the results in the soil maps as a basis for more extensive study by the local institutions of the best agricultural methods and practice in developing the highest commercial value of the soil areas.

In the Maryland work very close and cordial cooperation has been continued with the Maryland Geological Survey, Dr. William B. Clark, director, and with the Maryland Agricultural Experiment Station, Mr. H. J. Patterson, director. The Maryland Geological Survey, through cooperation with the United States Geological Survey, provided the base maps, and in addition paid the field expenses of the field party for one month. The experiment station paid the salary of one laboratory assistant, who has made an exhaustive study of the chemical constitution of the most important types of soil in Maryland, the results of which have just been published in a bulletin of that station.[1] It is hoped that the station may use the soil maps as a basis for an exhaustive investigation of the conditions of agriculture pre-

[1] The Chemical Composition of Maryland Soils. By. F. P. Veitch. Bulletin No. 70 of the Maryland Agricultural Experiment Station. January, 1901.

vailing in the State, with a view of developing the commercial possibilities of certain areas which are not producing what they should.

The North Carolina Department of Agriculture cooperated to the extent of having the area surveyed by a traverse party and paying the field expenses of the soil survey. The traverse work was done by a party of two men at a cost of about $1 per square mile. The work was constantly adjusted to an accurate railroad survey previously made by the United States Geological Survey, and the map so constructed was found to be very accurate and very satisfactory. The soil survey is to be used as a basis for systematic investigation of the fertilizer requirements of different crops through a series of substations to be established on some of the principal soil types. Hon. S. L. Patterson, commissioner, and Prof. B. W. Kilgore, State chemist, took an active part in this cooperation.

Cooperation has been continued with the Utah Agricultural Experiment Station, the station furnishing an assistant and paying his salary and field expenses, as was done in 1899. During the first part of the season Prof. Luther Foster was director of the station, and during the latter part Prof. J. A. Widtsoe, both of whom cooperated cordially with this Division.

The Arizona Agricultural Experiment Station, Prof. Robert H. Forbes, director, cooperated to the extent of providing an assistant and paying his salary and field expenses, besides furnishing valuable data, which had previously been collected, on the composition of the irrigation and seepage waters. Furthermore, Professor Forbes was in the field several times advising and helping the soil-survey party.

The Pennsylvania, Ohio, and California experiment stations were each unable to undertake any active cooperation by reason of a press of other work. The Ohio station, however, through Prof. Charles E. Thorne, director, took an active part in arranging plans for subsequent work in that State.

A full and close cooperation has been maintained, whenever possible, with the other Divisions of the Department. It was early recognized that in studying the adaptation of tobacco to different soils it would be necessary to have the cooperation of the Division of Vegetable Physiology and Pathology, and the cooperation with that Division has been particularly strong and efficient. We have not only been able to determine the cause of the fermentation of tobacco, but it has been possible in some cases to determine the nature of causes which have limited the production of crops or have impaired the quality. In studying the effect of alkali on the crops in the irrigated regions, such cooperation has in several cases enabled us to investigate the influence of the soil conditions upon the physiology of the plant and to investigate the possibilities of introducing the improved varieties which will withstand the prevailing soil conditions. The possibilities of this cooperative work with other Divisions of the

Department have been clearly seen and will be vigorously pushed as opportunities are presented in the future.

AREAS SELECTED FOR THE SOIL-SURVEY WORK.

The Lancaster area was selected for soil survey on account of its importance for general agricultural crops, as well as being one of the most important tobacco districts of the United States for the production of a cigar-filler leaf. Only a small portion of the county could be surveyed in the time allowed, but the results of this work fully justify the selection of this area. The results of the work will be a basis for the tobacco investigations in the improvement of the variety already grown and the introduction of new varieties on some of the soils. Montgomery County, Ohio, was selected for the same reason, as it is an important agricultural district and the center of the cigar-filler district known as the Miami Valley. Cecil, St. Mary, Calvert, and Kent counties, Md., were mapped, at the very urgent request of the Maryland Geological Survey and the experiment station, and in cooperation with these State institutions, as a basis for further efforts on the part of the local institutions for the development of new industries and the introduction of new methods in that State. An area in North Carolina was selected, at the request of the North Carolina Department of Agriculture, to furnish a basis for fertilizer and cultural experiments, looking to the introduction of new methods and new crops adapted to the different soils, particularly in the coastal plain region of that State. Two areas were surveyed in Utah in cooperation with the Utah experiment station in continuation of the cooperative work of last year. An area was surveyed in the Salt River Valley, Arizona, at the request of the Arizona experiment station and in cooperation with it, for certain problems which had interested the station and were of material interest to the people of the locality. Two areas were surveyed in California, one at Fresno and the other at Santa Ana, the first representing conditions in the San Joaquin Valley and the other in southern California, both important agricultural districts, and offering soil conditions which it seemed important to investigate.

LANCASTER AREA, PENNSYLVANIA.

Lancaster County was selected for the soil-survey work, as it is the most important cigar-filler district of the State, and is indeed the largest tobacco-producing county in the United States. It is one of the largest counties in Pennsylvania, embracing about 970 square miles. Only a portion of the field season could be spent here and only 270 square miles could be surveyed, but this was in the very richest part of the area, around the city of Lancaster. Besides being an important tobacco section, this is generally recognized as one of the finest and most fertile sections for general agriculture, and has

always been noted for the thrift and substantial success of the farmers. Many lessons could be drawn from the methods, manners, and customs that have contributed to this success which would be of value in other localities; but this would lead into other lines than soils, for it is unquestionably true that the prosperity of that section is dependent upon many causes other than the natural fertility of the soil. This fertility is undoubtedly great, and is an important contributing cause, but there are other areas naturally as fertile and with as favorable climatic conditions which are far behind this in present agricultural development. To one unaccustomed to the people and their customs, it is surprising that land values are still maintained at from $125 to $250 per acre in view of the competition from the West, while similar lands in other localities, with as favorable climatic conditions and with easy access to markets, are selling for $10 or $20 per acre.

The area in which the city of Lancaster is situated is a broad limestone valley, with sandstone and shale ridges, and in the southern part the Piedmont Plateau. The surface is gently rolling and is beautifully diversified. It is well watered by numerous streams, which furnish in the aggregate considerable water power that is utilized for mills and factories of various kinds.

Mr. Dorsey, in his report on the soils of this area, discusses the condition of agriculture in a way which the importance of the subject fully justifies.

The Hagerstown loam and the Conestoga loam are the most important soils, each covering nearly one-third of the area. They are both derived from limestone rocks, the former from hard massive limestone and the latter from a softer schistose limestone, locally called a sandy limestone on account of the rough surface of the rock rather than from the amount of sand contained in it. The soil contains a quantity of very fine mica, which gives it a soapy or greasy feel. The soil is usually not quite so deep and the surface is much more rolling than is the case with the Hagerstown loam area. The Hagerstown loam is the typical corn land of this portion of Pennsylvania, the Frederick and Hagerstown valleys of Maryland, and the Shenandoah Valley of Virginia, and stands for the finest type of land for general farming in the Eastern States. In the Lancaster area the principal crops for this soil are corn, tobacco, wheat, and grass. The soil proper is about 10 inches deep, resting on a clay loam, which in turn rests on a stiff red clay at 24 inches. The soils are naturally well drained and yet have sufficient body to retain manures and refuse from sod and stubble and an adequate water supply for crops, so that with careful and thorough tillage crops are sure and remarkably uniform from season to season.

The Hagerstown clay loam, derived from the same source and covering an area about half as large as the Hagerstown loam, is not so

much a general-purpose soil as the latter. It is heavier and more difficult to cultivate. It is not so well adapted to either corn or tobacco, but, on the other hand, it produces more wheat of a harder and better quality than the Hagerstown loam and makes a stronger and better grass land. The Hagerstown clay is still heavier and more difficult to till. It occupies in the aggregate but a small area, and is best suited to grass.

The Conestoga loam, whose origin has already been referred to, is a lighter soil than the Hagerstown loam, and is adapted to a rather lighter type of crops; for example, there is more chance of a thin wrapper leaf tobacco, although it is decidedly not a soil to be selected for this purpose. It is held in high esteem as a filler-tobacco soil and as a corn land.

The Donegal gravelly loam, covering only about 2.3 per cent of the area or 4,000 acres, much of which is occupied by the city of Columbia, produces a wrapper leaf which compares favorably with the Connecticut leaf. The character of the soil adapts it to this thin leaf and to truck crops.

The Edgemont stony loam is identical in character and physiographic relations with the mountain peach lands of Maryland, and there is evidence from the few orchards which are set out that this industry could be successfully and profitably developed. There is reason to believe also that a fair grade of wrapper leaf tobacco could be produced on these lands. They are adapted only to special industries and not to general farm crops.

The Hagerstown shale loam has a thin, naturally poor soil, which, however, by the thrift, energy, and intelligence of the people, has been made fairly productive. This soil is fairly well adapted to fruit, and gives promise of good wrapper leaf tobacco; this will be one of the areas which will be considered for this purpose in our tobacco investigation.

The Cecil mica loam is one of the typical highly micaceous loams of the Piedmont Plateau, adapted to general farm crops, but recently used extensively for crops for canning.

Enough has been said to indicate the general results of the soil survey in the Lancaster area. It has been shown that even in this thickly settled and most prosperous community there are such differences in the soils as to adapt them to different classes of agricultural crops and interests. The fact that this is already known, and that free use has been made in the soil survey of the experience of the farmers in the two hundred years that the country has been settled, argues nothing against the originality or value of the soil survey; but, on the contrary, the orderly arrangement of this experience, and a due attention to this in the classification of the soils in the consideration of new possibilities, give the strongest assurance of the value of such predictions as may be made and such comparisons as

may be drawn with other localities. The soil map accompanying this report, outlining the exact areas represented by the different soils, gives at once a comprehensive view of the actual soil conditions with their relative values and a basis for the development of new methods and new crops, which are assuredly necessary in the increasing competition in all lines of agricultural pursuits.

MONTGOMERY COUNTY AREA, OHIO.

Montgomery County is the most important tobacco-producing county of the Miami Valley, which is generally believed to produce the best domestic cigar-filler leaf of the Zimmer Spanish and other varieties grown there. It is a very different style of leaf from the Pennsylvania, and sells for about twice as much per pound. It was the consideration of these facts which led to the mapping of the soils of this area after the work in Pennsylvania had progressed far enough to show the conditions there.

Montgomery County covers an area of 480 square miles, and the soils of the entire county were mapped. The soils are entirely of glacial origin, the glacial deposit being so thick that the underlying native rocks contribute little or nothing directly to the character or crop value of the soils. The soils of the river and stream valleys, however, have been worked over and considerably modified by running water.

The surface of the county is generally level at a distance from the streams in the northern part, but quite broken and hilly in the southern portion, due to the stream action in what was once undoubtedly a very level plain. Mr. Dorsey, in his report, gives an interesting chapter on the history of the development of agriculture in the county, which is intimately related to the physiography and soils of the region. The first settlement was on the rich, black soils of the valley proper, about where Dayton is now situated. The uplands were considered much less desirable, especially as a considerable portion was wet and swampy and in need of drainage. Even tobacco was grown on these rich bottom lands, when the quantity rather than the quality of the leaf was the main point with the farmers. At present the leaf from these rich bottom lands is so coarse and rank that it has very little value, while the choice leaf is now grown on the uplands which were once considered unfit for this purpose.

Nearly 80 per cent of the county is classed as the Miami clay loam, which, with the Miami black clay loam, constituting 5.8 per cent of the county, form the upland portion of the county as distinguished from the river bottoms with their several terraces. The Miami clay loam is a strong productive soil, adapted to general farm crops and to the type of tobacco most in favor at the present time for cigar fillers. The soil is a loose light loam, about 12 inches deep, resting on a sticky clay loam that dries out into small cubes, which work up

like gravel when disturbed. These sugar-tree lands, as they are locally called, were originally held in slight esteem, and it is only in quite recent years that they have been used for the important crop of the locality—tobacco; but the character of the leaf produced on them is so fine that the cultivation of this crop is largely confined to these lands at the present time.

The Miami black clay loam, naturally wet and swampy, was the last to be taken up; under artificial underdrainage it has become very productive, especially for corn. After a few years of cultivation it makes fairly good tobacco land. It is not well adapted to clover nor to wheat, as these crops are apt to grow too rank.

The Miami sandy loam and Miami loam are both exceedingly fertile, but are both subject to occasional overflow from the river. They are used to a considerable extent for truck for the local market.

The Miami gravelly loam is the most fertile land of the county, producing large yields of corn especially. It was originally considered the choice tobacco land on account of the large yield, but the quality is much inferior to that of the Miami clay loam.

Montgomery County is decidedly the most uniform area surveyed during the season of 1900, although there are important differences in the soil and agricultural interests, as has been shown in this brief description.

CECIL COUNTY AREA, MARYLAND.

The soils of Cecil County were mapped in 1899 on a photograph of the pencil copy of the base map furnished by the United States Geological Survey, but the data were withheld from publication last year pending the completion of the lithographic work on the base map. The Maryland Geological Survey furnished one assistant and paid all the field expenses of the party.

The area of the county comprises about 375 square miles of land surface. It is situated in the extreme northeast corner of Maryland, and lies partly within the Piedmont Plateau of crystalline rocks and partly within the Coastal Plain formation with its gravels, sands, and clays. There is some difference in the climate of these two areas—due to the difference in elevation and to the proximity to large bodies of water—a great difference in soils, and consequently a marked difference in crops, and even in the character of the people, their habits and methods, and their material success. There are soils in each area representing the most barren as well as the most productive of the Atlantic Coast States.

The Piedmont Plateau region, covering the northern part of the county, is a broad, rolling plateau cut into by streams which have established good and sufficient drainage. The general elevation ranges from 200 to 400 feet above tide. The Coastal Plain area, on the contrary, is generally level, rarely rising to an elevation of 60 or 80 feet

except in the case of certain gravel or clay ridges and along the border of the Piedmont Plateau. The shore line is broken by several embayments, forming large river necks, which have important relations to the agriculture of the county.

On the Piedmont Plateau are the Cecil loam, Cecil clay, Cecil mica loam, Conowingo clay, and Conowingo barrens—given in the order of their relative area. Of these, the first four are quite productive and valuable farming lands, while the last named is quite worthless for any of our present crops. The Cecil loam and Cecil clay are closely related, in that they are derived from the same character of rock, namely, gabbro, gneiss, and granite, and have generally the same heavy red-clay subsoil. In the Cecil loam this clay is covered with about 12 inches of loam underlaid by about 12 inches of clay loam, while in the Cecil clay the stiff clay comes nearly or quite to the surface. The former is a typical corn land, while the latter is a wheat and grass land. The Cecil loam was formerly used extensively for wheat, and this crop is still used in rotation, but since the competition from the West and the consequent low price of wheat, other crops and interests have been introduced, notably the production of tomatoes and sweet corn for canning. The Cecil clay compares favorably with the most fertile soils of the State for general agricultural purposes. The Cecil mica loam is a highly micaceous soil occupying about 4 per cent of the area of the county. It has about the same agricultural value as the Cecil loam.

The Conowingo barrens, covering fortunately less than 1 per cent of the area of the county, has long been a matter of interest to the soil physicist and chemist. It is derived from serpentine and similar rocks containing considerable magnesia. The surface of the country is usually quite broken and hilly, and, as the rocks disintegrate but slowly, the soil is frequently washed away as fast as it is formed. In such cases there is but a mass of finely broken stone in which no valuable plants could be expected to thrive. There are many level areas, however, where the soil and subsoil have accumulated to a considerable depth, physically fit in every way to support useful plants, but which are yet quite unproductive. The most rational explanation of this fact as yet offered is that the preponderance of magnesia over lime is fatal to the plants. Dr. Loew[1] has pointed out that under these conditions magnesia may replace lime in some of the cell contents to such an extent as to impair the functions of the plant and prevent the proper assimilation of food. He suggests that in mild cases an application of lime will correct the evil and restore the fertility of the soil. Whether this is the cause of the barrenness of the soil, or whether, if this is the case, the application of heavy dressings of lime will correct the trouble has never been demonstrated, nor has it

[1] U. S. Department Agriculture Bulletin No. 18, Division of Vegetable Physiology and Pathology, page 42 (1899).

even been investigated in this area, so far as known. The matter is of the more interest, from a scientific point of view at least, from the fact that this soil survey has shown for the first time that a considerable area of soil derived from the same class of rocks, which we have called the Conowingo clay, is exceedingly productive and valuable, comparing in every way with the Cecil clay. The Conowingo barrens, where disintegration has gone on to any considerable depth, has a light-colored loam soil and a light-yellow clay-loam subsoil. The Conowingo clay, on the other hand, has a clay or clay-loam soil underlaid by a stiff, tenacious, deep red-clay subsoil. There is thus a marked difference in the character and appearance of the soil and an extraordinary difference in the character of the vegetation. What difference there may be in the chemical composition has not yet been determined, but is now being investigated.

Of the Coastal Plain soils, the Norfolk sand and the Sassafras loam each covers about 20 per cent of the area of the county, and while they are very different, each is very important for its own particular class of crop. The Norfolk sand is the typical truck soil of the Atlantic coast. It is a coarse sand, 3 feet or more deep, occupying low terraces and generally covering the points and sides of the river necks. These soils maintain usually from 6 to 8 per cent of moisture, and are adapted to early spring vegetables, which mature before the summer heat, or such crops as sweet potatoes and watermelons, which can stand nearly arid conditions. The soil has no value for field corn or other similar summer farm crops. Their value consists in ripening the vegetables early where there is no competition from the heavier soils, which, in fact, yield more, and frequently crops of better quality. As the truck crops are usually bulky, tender, and expensive to haul, and as the proximity to large bodies of water protects the crops from late frosts, the value of these lands is greatly influenced by the nearness to large bodies of water and by the facilities for water or rail transportation to the large cities. The truck industry has never been developed so much in Cecil County as in the more southern counties of the eastern and western shores of Maryland, and large areas of this Norfolk sand are at present unused.

The Sassafras loam occurs as broad, gently rolling or level terraces from 40 to 80 feet above tide level. The soil is a light-yellow loam 8 or 10 inches deep, resting on a subsoil of the same material, but rather heavier, and usually underlaid at 36 inches or deeper by gravel. This soil is generally well drained, but occasionally needs artificial underdrainage. It is light, mellow, easy to cultivate, exceedingly fertile, especially when well cultivated, and is good wheat land. This is the home of the old Maryland aristocracy, and there are many of the old colonial houses and old manor houses still standing. The land is still held in large holdings, too large for the most profitable management. When wheat was worth from $1.25 to $1.50 per bushel,

as it was until a few years ago, these farms yielded handsome incomes, but with competition from the West and with occasional low yields, except under intensive cultivation and fertilization, new crops, new methods, and new industries have had to be introduced, and these have been slow in establishing themselves. The fruit industry flourished for some years, and recently the canning industry and dairying have been introduced to some extent.

The Susquehanna gravel and Susquehanna clay have little agricultural value. The former, covering about 19 per cent of the county, is a deep, gravelly soil, of little value for any of our present agricultural crops. In other localities such soils are used for vineyards, but it is questionable if this industry would be successful in this locality. The Susquehanna clay is a stiff, intractable clay, which has little or no value. No satisfactory explanation can be given for the low agricultural value of these lands, as the texture of the clay is the same as of the Hagerstown clay, which is the most valuable soil in the East for general agricultural purposes, and the chemical analysis would indicate that the soil was exceedingly fertile. This is one of the problems which neither the soil physicist nor the chemist has been able to solve. The Elkton clay is apparently formed of the same material as the Susquehanna clay, but reworked in some past geological age. This soil is quite fertile and capable of a high state of cultivation by proper methods, including underdrainage when this is needed, as is often the case.

Mr. Dorsey dwells at length, in his report, upon the agricultural conditions of the county and on the relation of these different soils to the industries and prosperity of the people.

ST. MARY COUNTY AND CALVERT COUNTY AREAS, MARYLAND.

St. Mary County covers an area of about 360 square miles of land surface and Calvert County about 218 square miles. The same types of soil are found in the two areas, but owing to certain geological reasons the relative extent of the soils is very different in the two counties, and there are certain important physiographic differences which have an important bearing upon the agricultural conditions.

Both counties lie wholly within the area of the Coastal Plain, and consist of unconsolidated material, which was originally laid down in nearly horizontal beds under water. The upland portion of the counties now varies from 90 to 200 feet above tide level. Numerous streams have been dissecting and carrying away the soft material until Calvert County, especially, is left as a very hilly area. As the materials composing the different soil types are not very thick, the soils are very patchy, especially in the middle and southern portions of Calvert County, and are rarely found in continuous tracts of any size, and most farms have more than one of the eight types of soil. This is distinctly unfortunate, as often no large interests can be developed,

as the soil conditions are limited; besides, the soils in small patches are apt to be mixed and not true to type as when they are in large areas.

In St. Mary County the surface is less eroded and less hilly, and there are generally larger continuous areas of uniform soil conditions. The topographic sheets were a great aid in mapping the soils of both of these areas, as well as in understanding the distribution of the soils, which is largely dependent upon stream erosion. The general sequence of the soils with elevation near Leonardtown gives the Norfolk loam the highest position. Under this loam, or at lower elevations where this has been removed or was never deposited, is the Leonardtown loam (wheat and corn land). Under this is found a layer of gravel 5 feet thick, which is exposed as a fringe or border where the Leonardtown loam has been removed, and is called the Susquehanna gravel; below this gravel, or at a lower elevation, is the Norfolk sand (truck land), and at the lowest elevation is the meadow land. The Sassafras sandy loam and Sassafras loam are terraces constructed in comparatively recent periods, while the Windsor sand is probably a modified form of the Norfolk sand and Susquehanna gravel, mixed.

The Norfolk loam covers, as a fairly continuous area, about 4 per cent of the upland of St. Mary County, and in small irregular areas about 4 per cent of Calvert County. It is a fine sandy loam underlaid by a somewhat heavier subsoil. This is a typical soil for pears and small fruits, such as raspberries, blackberries, strawberries; for heavy truck crops, such as cabbage, spinach; and also for peas, tomatoes, and similar special industries. As a matter of fact, the soil is used for corn, wheat, and tobacco, the usual rotation in southern Maryland.

The Leonardtown loam is a very much heavier type of soil. It covers about 41 per cent of St. Mary County and about 6 per cent of Calvert County, occurring in the latter in small, isolated patches. The soil is a yellow silty soil, resembling loess in texture, underlaid by a clay subsoil of peculiar structure. The clay is in flattened lenses, separated by layers or pockets of sand. This soil has been cultivated for upward of two hundred years, but it is now little valued and is covered with oak and pine over much of its area. It is worth from $1 to $3 per acre. The cultivated areas produce small crops of corn, wheat, and an inferior grade of tobacco.

The generally low estimation in which land is held is probably wholly unjustified. There are two or three farms in the area which, under a high state of cultivation with intelligent methods, will produce from 20 to 30 bushels of wheat per acre and corresponding crops of corn. Clover does very well and grass fairly well. The poor results generally obtained are due largely to the economic and social conditions peculiar to this section, and to the poor methods and scarcity and inefficiency of the labor. The lands are generally acid, undoubtedly need lime, and frequently need underdrainage. In texture, in chemical

composition, and in agricultural value (when carefully and intelligently farmed) these lands compare favorably with the Hagerstown loam of western Maryland and Lancaster County, Pa., which are considered the most valuable soils of the Atlantic States for general farm crops. The Lancaster soil sells for from $125 to $250 per acre. The Leonardtown loam, even when cleared and cultivated, will hardly bring $10 per acre. The Lancaster soil is cultivated by the owner and his large family. Everything possible that is needed by the family is grown on the farm and in the garden—meat, vegetables, preserves, flour, meal, dairy products, are provided in the greatest abundance and variety. Even the sugar is often made on the place. Little is shipped out of the county except tobacco and stock; but home industries are patronized and home markets supplied, the two nearly balancing. The result is a thrifty, contented, and happy people.

The Leonardtown loam is farmed with inefficient labor by overseers or by tenants on shares. Only corn, wheat, and tobacco are grown, the corn being fed to the working stock and the wheat and tobacco being sent out of the county in exchange for meat, flour, and even vegetables, canned fruits, and butter, which the Pennsylvania farmers provide from their farms and gardens at little or no outlay of cash or credit. Added to this unthrifty method are the mortgages resulting from the changes due to the civil war, and it is little wonder that many people are disposed to invoke legislation to correct the evils, that the young men leave the farms and flock to the city, and that the Leonardtown loam is held in slight esteem. The soil is worthy of more consideration, as it is capable of a much higher development than is generally attained under existing conditions and with the present methods. No clearer lesson has been taught by the soil survey than this.

The Susquehanna gravel, although widely distributed, occurs generally in narrow bands, and covers in the aggregate but a small part of each county. It is a coarse, gravelly soil, quite unsuited to any of our staple agricultural crops.

The Windsor sand covers about 18 per cent of Calvert County, but only 2 per cent of St. Mary County. The soil is a coarse sand mixed with fine gravel, frequently designated as "pine barrens," and is conspicuous along the Atlantic coast from New England south. Until a few years ago, and even yet, it is in many localities considered a well-nigh worthless soil for agricultural crops, but it is used to a considerable extent in Calvert County for peaches. The orchards last a long time and the fruit has an excellent color and quality. It is probable that with intensive culture and further specialization this soil may have considerable value. It has little or no value for general agricultural purposes.

The Norfolk sand covers 42 per cent of Calvert County, but only 12 per cent of St. Mary County. It is a coarse sand, resting on a sandy

subsoil 3 feet or more in depth. It is the typical truck soil of the Atlantic coast, although it is not used to any great extent for this purpose in the two counties under consideration. This is partly due to the lack of easy and quick transportation and partly to the fact that the lands are elevated and at a distance from the water, where the crops would be protected from the late spring frosts. This soil grows an excellent grade of the Maryland type of tobacco.

The Sassafras loam and Sassafras sandy loam are both terrace formations. The former is a loam soil, resting on a red or yellow clay subsoil, and is an excellent corn, wheat, and grass land. The latter is much lighter in texture and is a corn and tobacco land. Both of these soils are highly esteemed, and as a rule are better farmed than any of the other soils of the two counties.

The meadow land covers about 23 per cent of the area of St. Mary County and about 11 per cent of Calvert County. As a rule, this land needs underdrainage, but when underdrained it is a strong and fertile soil, well adapted to corn, wheat, and grass.

Mr. Bonsteel has fully discussed the geologic origin of these soils, their character, and their relation to crops and agricultural industries in his report.

KENT COUNTY AREA, MARYLAND.

Kent County covers an area of about 315 square miles and the soils of the entire county were mapped. It is entirely within the area of the Coastal Plain and consists of an upland portion, ranging from 50 to 100 feet, and of a lowland portion, ranging from 10 to 40 feet above tide. With one important exception (the Sassafras gravelly loam), the soil types of Kent County have all been described under Cecil County. Mr. Bonsteel discusses fully in his report the relation of these soils to crops and agricultural industries, and the map accompanying this report shows their area and distribution.

NORTH CAROLINA AREA.

The soil survey in North Carolina was started at the instance of the North Carolina Department of Agriculture as a basis for the fertilizing tests it proposed making on some of the important types of soil in that State. The area between Raleigh and Newbern was selected because it crossed the Coastal Plain, with its variety of soils and agricultural interests, and because an accurate survey had been made along the railroads connecting these two places by the United States Geological Survey. As there were no reliable maps, the North Carolina Department of Agriculture put a traverse party in the field, and thus provided a very satisfactory base map for the soil-survey work as it progressed.

It happened that the area extended for a considerable distance adjacent to the Neuse River, and it is probable that that stream had

great influence upon the character of the material at the time or subsequent to the time the soils were laid down. There are evidences that the stream bed has been shifted and that it has at places widened out in numerous embayments. Some such conception is necessary to explain the great variety of soils, but even with this no satisfactory reason can be seen for the very confused distribution of the soils and the juxtaposition of soils of totally different texture in certain parts of the area. For example, it is difficult as yet to explain the occurrence of small areas or patches of gravel surrounded by silt or sand at no perceptibly different elevations. However this may be, it seems probable from other general observations that there is a greater variety in this area than in an area of similar dimensions at a distance from the river.

There are sixteen distinct types of soil in the area. Of these, the Cecil clay, derived from the weathering of crystalline rocks of the Piedmont Plateau, is a strong clay soil adapted to wheat and grass; the Selma silt loam, the finest type of bright tobacco soil; the Norfolk sand, a typical truck land; the Garner stony loam, a nearly worthless soil, and the Savanna and Pocoson, representing types of swamp lands which need extensive improvement in the way of drainage before they are of value for crops. The soils represent conditions therefore adapted to a wide variety of agricultural interests. The peculiarity of the soils will be briefly stated, the position and relative area of each being shown upon the four maps accompanying this report.

The Cecil clay, as already stated, is the product of disintegration of the crystalline rocks of the Piedmont Plateau, and is similar in all essential respects to the soil under the same name in Cecil County, Md. The soil is a red clay, 6 inches deep, resting on a stiff tenacious red clay. Both the soil and subsoil contain considerable quartz and rock fragments, sufficient to obstruct cultivation to a considerable extent and to be very wearing upon implements. These fragments insure good drainage, however, especially as the broken quartz is arranged in perpendicular veins in the subsoil. The soil when well tilled makes the best wheat and grass land of the locality, and is also an excellent cotton and corn land. It is decidedly the strongest and best soil for general farming and stock raising in the area.

The Cecil sandy loam has the same origin as the Cecil clay, but differs from it in having from 6 to 10 inches of a brown sandy loam overlying the stiff red clay. Both soil and subsoil contain the same quartz and rock fragments as the Cecil clay. The red clay subsoil insures a uniform moisture content, and the land withstands drought well. The soil is adapted to cotton and grain, and some bright tobacco is raised on it.

The Durham sandy loam is closely related to the two preceding types, being composed of the same material, although partly of sedi-

mentary origin. It has the same quartz and rock fragments, although the quartz veins do not occur in the subsoil and the subsoil clay is of somewhat different character. The soil also contains more sand than the Cecil sandy loam. It is better adapted to corn, bright tobacco, and truck than to cotton or small grain. All three of these types are quite rolling or even hilly.

The Norfolk sandy soil is a coarse, sharp sand or sandy loam, 10 to 20 inches deep, resting on yellow clay. There are no rock fragments in this nor in the remaining soils, except in two types, which will be specifically described. The surface is generally level. It is not adapted to small grain, is fairly well adapted to cotton, but is well suited to corn, bright tobacco, and truck.

The Norfolk fine sandy loam differs from the above only in the character of the soil. It consists of a fine-grained sandy loam, 10 to 15 inches deep, resting on a rather stiff yellow clay. The surface is generally level. It forms a large and important type in the area surveyed. The clay subsoil holds fertilizers and maintains moisture so that the soil withstands droughts well. It is an excellent cotton soil, and is well adapted to corn, bright tobacco, and truck.

The Norfolk sand is the typical early truck soil of the area, as it is of the whole Atlantic coast. It is a deep sandy soil, 3 to 6 feet or more in depth. It is generally loose and incoherent, and makes sandy roads, although it varies somewhat in texture. It is not well adapted to either cotton or corn, except under the intense cultivation and heavy fertilization given for truck. It is used almost exclusively for truck growing for the early markets, and is the more valuable the nearer the water, where protection from frosts is afforded and cheap transportation is possible.

The Goldsboro compact sandy loam consists of a sharp sand which compacts on drying, forming firm, hard roads, and requires constant cultivation, especially after rains, to prevent the formation of crusts. When allowed to dry without stirring, it is frequently difficult to plow, and is not in good condition for crops. In low-lying areas it frequently needs artificial drainage. There is little or no difference between the soil and subsoil. It is fairly well adapted to cotton and corn.

The Selma silt loam is a gray silt, 18 inches deep, overlying a mottled yellow clay subsoil containing some fine sand and small gravel. It is possible that this might be correlated with the Leonardtown loam of the Maryland areas, which it closely resembles. The surface is gently rolling and the drainage is good, except in a few low places. This is a fine cotton soil, and one of the most valuable soils for bright tobacco especially, as occasionally happens when the silt contains an admixture of fine sand, permitting more perfect drainage, a condition which renders the soil less fit for cotton.

The Selma heavy silt loam consists of a heavy compact silt 10 to 20

inches deep, overlying a stiff mottled clay. It occurs generally in flat, level areas, poorly drained, and generally requiring artificial drainage. When drained it is well suited to cotton, much better in fact than to any other crops of the locality. It is not at all suited to bright tobacco.

The sandhill soil is a coarse, loose, incoherent sand, 10 feet or more in depth, little adapted to any agricultural crop, owing to the small water-holding power of the soil. It occurs generally as low hills, and the sand is often from 20 to 60 feet deep. Recently peaches have been tried with some success. The fruit has a rich color. The soil is generally uncultivated, and supports a growth of scrub oak and pine.

The Neuse clay is a stiff, silty or fine sandy loam, 10 to 20 inches deep, underlaid by a stiff mottled clay subsoil. It is generally subject to overflow in time of freshets, and is used mainly for pasture or left to forest growth. It is difficult to till in wet or in dry seasons, and is little esteemed for farm purposes.

The Garner stony loam, 6 to 15 inches deep, consists of a sandy loam containing from 40 to 60 per cent of rock fragments and gravel often of considerable size, underlaid by a stiff red brick clay. The soil packs firmly over the clay subsoil, affording firm roads almost equal to macadam. The surface is quite rolling, and this thin veneer extends over the whole area, rendering it exceedingly difficult to till and almost valueless for agricultural purposes. It supports a forest growth, however, containing good merchantable timber, principally pine.

The Susquehanna gravel is a very gravelly soil of small extent and of little agricultural value.

The Savanna is a physiographic type rather than a soil type. It is a low flat area with poor surface and under drainage. The country is often flooded for considerable periods from the ordinary rainfall of the locality. It is generally sparsely wooded, but supports an abundant growth of cane and coarse grass, which afford good pasturage. It can nearly always be drained, but on account of the level surface and broad extent this is a difficult and costly operation. When drained it is adapted to cotton and corn. It is, however, seldom cultivated.

The Pocoson is also a low-lying area, generally swampy, and having a black, spongy, mucky soil. It supports a sparse growth of scrub pine and a very thick growth of grass, bushes, and vines. In dry seasons it affords good grazing. In such seasons there is danger from fire, which burns not only the grass but also the mucky soil itself, which ruins the pasturage for some time. When cleared and drained the land is excellent for cotton and corn, but only small areas have been so reclaimed.

A few areas of muck are found in the area surveyed, but these are usually of small extent, and make fertile corn lands when drained.

Few areas of cypress swamp were encountered, and these were of small extent.

It is thus seen that, although a large number of soil types was encountered in the area, they all have quite distinctive characteristics, and are adapted to different interests or have different crop values and require different treatment. Mr. Smith treats at length of the agricultural conditions in his report.

WEBER COUNTY AREA, UTAH.

About 310 square miles were mapped in this area, which includes the whole of Weber County and part of two other counties. The area is naturally divided into three agricultural districts—a broad delta plain upon which Ogden is situated and which embraces all of the irrigated lands; an upland portion sloping up to the mountains, generally too high for irrigation, rough and uneven in surface, and used only to a small extent for dry farming to wheat; and a lowland area of about 100 square miles, from which the lake has but recently receded and where the land is so salty that no vegetation will grow. The delta plain is quite thickly settled; the farms are small, and intensive cultivation is the rule. Peaches, pears, prunes, and plums are important fruit crops; sugar beets are grown to supply one large factory; tomatoes are grown for eight large canning factories, and other truck crops are produced.

Eight soil types are described in Mr. Gardner's report, each differing from the other in some physical character and generally in crop relation.

The Fresno fine sandy loam, covering about 43 per cent of the area, is the most important type. A small portion of this land slopes toward the mountains, some of it containing gravel. Where it is too high for irrigation it is dry farmed to some extent to wheat. Where it can be irrigated the gravelly areas are admirably adapted to peaches and other stone fruits; where the gravel is absent or far below the surface, the irrigated land is adapted to apples and pears. The delta portion, which is generally free from gravel, when well drained and free from alkali, is well adapted to grain, sugar beets, tomatoes, small fruits, general truck crops, as well as apples and pears. The soil is a fine sandy loam, 6 feet or more in depth. On account of the low-lying position, it is poorly drained in places, and in such places contains excessive quantities of alkali.

The Fresno sand is second in point of agricultural value and third in extent, covering about 11 per cent of the area. The soil is a loose and incoherent sand, having about the same texture to a depth of 6 feet or more. Some of it extends above the canal, and is dry farmed to wheat. It is adapted to the general crops of the locality as mentioned above. Considerable trouble and damage have resulted from

the rise of the water table from seepage and the rise of alkali. This can be prevented and the damaged land reclaimed by underdrainage, but this has not been attempted, and when the conditions get too bad the lands are abandoned.

The Jordan loam comes next in agricultural value, covering about 8 per cent of the area. It is heavier in texture than the soils just described, requiring more care in cultivation and irrigation and more often needing underdrainage to remove seepage water and alkali. When well drained it is adapted to alfalfa, grain, apples, and pears.

The Salt Lake sandy loam is the second largest in extent, covering about 25 per cent of the area. It is a fine loam for about 18 inches, underlaid by fine sand. The soil is quite worthless for crops, owing to the enormous quantity of salt it contains (from 3 to 10 per cent). Since 1868 the level of Great Salt Lake has fallen 14 feet. This is partly due to unexplained fluctuations, partly to evaporation, and largely to the diversion of the waters before they reach the lake, for irrigation purposes. This Salt Lake sandy loam is the recent lake bottom, and this accounts for the large amount of salt it carries. The land is so low and flat and contains so much salt that its reclamation would be difficult and certainly would not be justified at the present time. Standing water is generally reached within 3 feet of the surface.

As the other soils cover small areas, it will not be necessary to mention them here.

A lime hardpan occurs over certain portions of the area from 18 inches to 3 feet below the surface. Mr. Gardner gathered some valuable information regarding this hardpan, the formation of which Dr. Cameron and he have explained, but as yet it is not possible to offer any suggestion for a practical remedy. The whole subject of hardpan formation and the treatment of it is being investigated in the laboratory of the Division. The outline of the hardpan areas are shown on the soil map.

The irrigation water of the district is exceptionally good, and free from alkali. There is more than enough water in the early spring, but frequently a shortage in the summer and fall. The project for storing water for the latter season is being agitated in the district. The main canals aggregate about 130 miles in length, and the laterals considerably more than this. Running for the most part over deep sandy soils with no protection, there must be a very large amount of seepage. While no actual measurements were made, Mr. Gardner estimates that fully half the water is lost in this way, not only needlessly wasting the water but imperiling the land. Much damage has already resulted from the rise of subsoil waters and the rise of alkali, and over most of the area standing water can be reached at 6 feet from the surface. Mr. Gardner in his report rightly dwells upon the serious aspect of this and the necessity of preventive measures in

the construction of the canals and the underdrainage of the land. Most of the canals are owned and controlled by the land owners.

The chemical analyses of the alkali in the soils in different parts of the area indicate that it consists of about 41 per cent of sodium chloride, 8 per cent potassium chloride, 9 per cent sodium carbonate (black alkali), and 24 per cent sodium bicarbonate. The alkali map accompanying this report shows the percentage of the alkali in the soils of the region.

It is estimated that there are about 137,000 acres which are or could be irrigated (although there are only about 40,000 acres actually under irrigation). The whole area surveyed contains about 198,400 acres, of which about 83,000 acres have so little alkali as to be at present absolutely safe for cultivation. About 16,000 acres have enough to make their cultivation at least risky, and there are 110,000 acres containing too much alkali for crops, or 50,000 acres exclusive of the lake bottom soil, and this area is increasing. The gravity of the situation is thus seen, and the actual depreciation of property value in the district can easily be estimated when it is stated that good lands are worth $100 an acre and lands set in orchards are valued at very much more than this.

SEVIER VALLEY AREA, UTAH.

The survey in this locality included all the soils of the valley from Joseph to Gunnison, a distance of 45 miles, embracing an area of about 220 square miles. The valley has an average width of about 5 miles, and is bounded on either side by high mountains. The surface of the valley is quite level. Mr. Gardner secured a number of illustrations showing the general character of the farm lands of the valley and of the towns. Few people live on their farms, but live in the towns and villages.

The soils as a rule are light in texture and well drained. They are mostly derived from the adjacent mountains, the material being often modified by stream action, and are underlaid in many places by gravel beds. The soils are derived from different kinds of rocks, and have well-defined physical characteristics, but these differences are not such potent factors in determining crop values and crop distribution as in the Eastern States. As a rule, the virgin lands carry considerable alkali, but the drainage is so good that usually the alkali disappears after irrigation has been practiced for a season or two. The water supply is generally of good quality but not very abundant, so that great care has to be exercised in its use. This has been of value in one respect at least, namely, that after the alkali originally present has been removed so much care is used in applying water to the land, and so little water is used, that little trouble has been experienced from seepage and subsequent accumulation of alkali, except in certain parts of the valley, notably near Richfield, where there has been

such an abundance of water that considerable areas of once valuable land are not at present fit for cultivation owing to the wet condition of the soil and the accumulation of alkali. The alkali problem, so serious in other places, is not considered of much moment here. The effect of increasing the available water supply, and the more liberal and extensive use of water would probably be proportional to the texture and drainage conditions of the several soils, which can be seen from the description of the soils in Mr. Gardner's report, bearing in mind always the relative elevation of the different soils with reference to the irrigation canals and the care taken to prevent seepage or loss of water from the canals. The conditions of Salt Lake County, reported last year, show that soils which would be considered well drained may be filled with water and alkali by seepage from a canal situated at some higher elevation, which was not properly constructed in passing through a gravelly loam.

The conditions in the Sevier Valley teach one very important lesson, namely, that with good drainage and the use of moderate quantities of water, alkali can easily be removed from soils originally containing large quantities. That with the careful use of water, these favorable conditions will continue, is attested by the fact that the lands are still in good condition after years of cultivation. That the more liberal use of water may cause a rise of alkali is attested by the conditions near Richfield and by the conditions in Salt Lake County, where lands which were filled with alkali when first settled, but which were readily removed by the early irrigation, have since gone to alkali again, with no possibility of reclamation without artificial drainage. The latter stage is far more serious than the first.

Mr. Gardner discusses in his report the character of the soils, the basis of their classification, their crop values, and their relation to drainage and alkali in such detail as to give a very clear conception of the actual conditions, and brings out many points of local interest.

The irrigation water is unusually good except at a few points, which are pointed out in the accompanying report, where seepage water raises the salt content to near the danger point. The actual salt content is given for many samples of water from canals, springs, rivers, artesian wells, driven wells, surface wells, and seepage streams. The best waters contain from 15 to 75 and average about 35 parts of solids per 100,000 parts of water. The alkali in the water contains nearly equal proportions of chlorides, sulphates, and bicarbonates, with but a trace of carbonates. The alkali of the soil contains on the average 39 per cent of sodium chloride, 25 per cent of sodium sulphate, with a variety of other salts in much smaller proportion. Sodium carbonate, or black alkali, is rarely found in any considerable quantity, but bicarbonates are always present, often in very large quantities, not only in the soil, but in the irrigation water, as before noticed, sometimes amounting to over 40 per cent of the salt

present. This district is peculiar in this respect, so far as our investigations go and so far as the special literature on the subject of alkali lands shows. The maps show that nearly 80 per cent of the entire area is free from injurious amounts of alkali, and the drainage is so good that much of the remainder may be easily and safely reclaimed when it is brought under irrigation by the judicious application and use of water.

SALT RIVER VALLEY AREA, ARIZONA.

The soils were mapped around Tempe, Phoenix, and along the Buckeye Canal, over an area aggregating about 370 square miles. The surface of the country is a valley or plain, with a gradual slope toward the mountains on either side. The soils are colluvial, that is, derived from mountain waste, and alluvial, or stream deposits. The former class comprise the Maricopa gravelly loam, lying nearest the mountains, Maricopa sandy loam, Maricopa loam, and Maricopa clay, in successive distances toward the center of the valley. The alluvial soils comprise the Salt River gravel, Pecos sand, Gila fine sandy loam, Glendale loess, and Salt River adobe. It is thus apparent that there is a great range in soil conditions. The character of these soils, their crop values, and their relation to drainage and alkali are discussed by Mr. Means at length in his report. The water is generally good, and no trouble is experienced from alkali when the drainage is good. Where the drainage is deficient and subirrigation occurs, alkali may accumulate in such quantities as to be injurious to crops. Such injury can be prevented and injured lands reclaimed by underdrainage. Decidedly the wisest courses are preventive measures in the protection of ditches from seepage and economy in the use of water. Such care is requisite from the further fact that the water supply is not very abundant. This scarcity of water is indeed a serious problem in the development of an immense area of extremely fertile soil under a nearly ideal climate for semitropical agriculture. In order to irrigate the land already under cultivation considerable seepage water has to be used, which has a marked effect in raising the salt content of the irrigation water, especially of the Buckeye Canal; and were it not for the fine natural drainage of the soils trouble might be feared from the accumulation of alkali in the soils in that area. In the Tempe area there is considerable trouble from seepage water and alkali in the lowlands since the irrigation of the higher mesa was undertaken. In times of scarcity of water, however, the level of the underground water in the lowlands falls from 6 to 10 feet, the alkali is readily washed down again, and the lands are reclaimed through the ordinary methods of irrigation. Here again is a striking lesson of the value and necessity of thorough drainage in attacking the alkali problem.

While the virgin soils and the well-drained irrigation soils are notably free from injurious quantities of alkali, the well waters all carry

large quantities of alkali, indicating an abundance of alkali in the lower depths of the subsoil, and it is the rise of this which is to be feared. That this can be prevented, is clearly shown by the investigations. The alkali is mainly sodium chloride, with small quantities of numerous other salts. There are very small quantities of sodium carbonate. Professor Forbes has called attention to the general presence of nitrates in the irrigation waters, and in one instance (sample 4416) Mr. Means found the top inch of soil to contain 41.20 per cent of soluble matter, of which 20.53 per cent was sodium nitrate and 15.08 per cent potassium nitrate. This, however, is the only instance where nitrates were found in any quantity in the soil or alkali crust.

Mr. Means dwells at some length upon the remarkable development of the agricultural industries of the locality and of the much greater possibilities if an adequate water supply can be secured through storage of storm waters. There is no doubt that there are vast areas of lands lacking only water to make them extremely fertile. The possibilities of development of extensive areas have been considered by engineers.

Very favorable reservoir sites are known to exist in the mountains around the valley. On the Salt, Gila, Agua Fria, and Hassayampa rivers reservoir sites have been surveyed, and in several instances the plans for dams and canals have been drawn and the cost of the construction estimated.

Lippincott, in Water-Supply and Irrigation Paper No. 32, of the United States Geological Survey, estimates the cost of storage of water on the Gila River for three dam sites as follows:

Cost of storage of water on the Gila River.

Location.	Acre-feet.	Cost per acre-foot.
Buttes dam	174,040	$15.19
Riverside	221,138	9.01
San Carlos	241,396	4.30

The San Carlos dam site is in his opinion the most satisfactory place for storage. Sufficient water for the permanent irrigation of 75,000 acres of land can be stored there, and, according to Mr. Lippincott, the supply of water is sufficient to fill the reservoir every year.

On the Salt River the construction of a dam below the mouth of Tonto Creek will impound 800,000 acre-feet of water. This dam site is considered one of the most favorable known.

At least 4 or 5 acre-feet of water should be stored for each acre to be irrigated to allow for the loss by seepage and for the seasons of deficient precipitation. With this allowance the storage of water for 1 acre in the San Carlos reservoir, which is the most economical of the three sites above mentioned, from the Gila River, would amount to

about $20. In the Buttes reservoir it would be more than three times as much. These figures are capable of being fairly accurately estimated by engineers, and the enterprise would doubtless be very successful if this cost could be assessed and collected from each of the 75,000 acres which could be developed by the San Carlos reservoir; but it is this uncertainty and impossibility of disposing of all the land and the water right that has operated against these large irrigation schemes in the past, and is making it difficult to induce capitalists to promote these enterprises.

Another very serious difficulty encountered in this section against the storage of water is the very large amount of sediment carried by the flood waters. This is a factor which is far more serious in some places than in others. In many of the Colorado rivers very little sediment is carried, and there is very little danger from this cause, but the amount of sediment carried by these Arizona rivers is so large that it would fill up a reservoir in a few years. Engineers are at work on this subject not only in this country but in other irrigated countries, and while various schemes have been suggested, no satisfactory solution of the problem has been devised. Mr. Means speaks in his report of the notable quantity of sediment which has been deposited, sufficient in certain cases in the area which he surveyed to entirely modify the character of the soils even within historic times. It is quite a problem to keep the canals of sufficient depth, and the sediment thrown out of them is so high now in many cases as to make the further disposition of sediment a serious problem.

While the problems presented in this Arizona area are serious, they are by no means of such a nature as to be considered insurmountable, and there is no reasonable doubt but they will be solved in time.

The remarkable development of the present industry, and the wonderful possibilities which are apparent, indicate that they should be met and solved as many, seemingly as difficult, problems have been solved before.

FRESNO COUNTY AREA, CALIFORNIA.

The district surveyed extends from the foothills of the Sierra Nevada Mountains down into the trough of the valley, covering an area of about 625 square miles and including all the irrigated lands tributary to Fresno. There are three main physiographic features—the rolling foothills, the plains, and the bottom lands along the rivers. The foothill soils are derived from the disintegration of crystalline rocks in place. The plain soils are derived from well-stratified deposits of clay, sand, volcanic ash, and sandstone, the material being derived originally from the wash from the mountains laid down under water when what is now the great valley was much lower in elevation and constituted an arm of the ocean. The soils of the plains may be thrown into two great classes, one derived from the red sandstone

formation and the other of a white deposit, consisting of alternate layers of sand, clay, and volcanic ash.

The foothill soils comprise the sierra adobe and the San Joaquin black adobe, both of which are used mainly for grazing, on account of the difficulty and cost of getting water to them for irrigation. They are used to some extent for dry farming to wheat, and where water is available they are adapted to citrus fruits. The elevation insures a protection from frost not enjoyed by localities in the plains and makes possible the citrus fruit industry. This industry, although new, is very promising.

Forty per cent of the area surveyed is covered by the Fresno sand and 17 per cent by the Fresno sandy loam, the only soil types represented as derived from the white formation. The Fresno sand corresponds very closely in texture and in crop value with the truck soils of the Atlantic coast. It is a loose, coarse-grained, incoherent sand, thoroughly drained and seldom containing an excessive amount of alkali. The Fresno sandy loam, on the other hand, is a more compact sand with less perfect drainage, locally known as the white-ash land on account of the white color and the ashy texture of the material. There is a soft white hardpan underlying both of these soils, usually 3 to 6 feet from the surface in the Fresno sandy loam area, which carries considerable alkali, and when the drainage is deficient, by reason of the low-lying position of the soil, or from an excessive application of irrigation water, or seepage from the canals, this alkali is liable to rise to the surface and render the land more or less unfit for agricultural crops. The danger of this rise of alkali is very much less with the Fresno sand on account of the better drainage afforded by the more open texture of the soil. The Fresno sandy loam, or white-ash land, was originally considered extremely productive, and is now, where the drainage is good. Some of the first colonists settled on this land through choice. The alkali did not show on the surface, and only appeared after some years of irrigation, when considerable money had been invested in farm improvements.

The Fresno red sand, San Joaquin sandy loam, Fancher sandy loam, and San Joaquin red adobe are all derived from the red formation. These soils are mainly north of Fresno, while the soils derived from the white formation are mainly south of that city. The red formation overlies the white formation, and contains very little alkali. A section at the bluff at Herndon shows the red sandstone in thin layers, interbedded with sand and clay extending to a depth of 40 feet; and under this is the white formation, containing considerable quantities of alkali, which forms the surface of the country south of Fresno. The soils derived from the red formation are generally free from alkali, but the San Joaquin sandy loam and San Joaquin red adobe usually have layers of red sandstone hardpan under them and quite close to the surface. Where this hardpan comes to within 3 feet of the sur-

face, irrigated crops generally fail, but the lands may be successfully dry farmed to wheat, which is grown over extensive areas. Successful attempts have been made to blast out this hardpan in setting trees or vines, but at a cost of $40 or $50 per acre. Where the hardpan is considerably more than 3 feet below the surface it does not seem to interfere with irrigation or with irrigated crops. The main problem, therefore, in the area south of Fresno is the danger from alkali which is found in the soft white hardpan under the surface, while the most serious problem north of Fresno is the occurrence of the sandstone hardpan, which comes quite close to the surface under some of the soils.

Mr. Means dwells at length in his report upon the character of these various soils, their crop values, and the methods adapted to their cultivation. He also discusses quite fully the character of the two kinds of hardpan and the problems connected with their occurrence.

The irrigation water is exceptionally good, containing less than 8 parts of solid matter per 100,000 parts of water. Mr. Means calls attention to a fact mentioned in other publications of this Division, that the ground water which was originally from 70 to 150 feet below the surface can be reached at present at from 10 to 20 feet anywhere in the irrigated district, while immediately around Fresno standing water can be reached during the irrigation season at from 3 to 10 feet below the surface, which is a menace to agricultural crops and is a matter which should receive attention and be carefully watched. The water level varies greatly, frequently rising 5 or 10 feet during the irrigation season. The surface wells in the red formation north of Fresno have generally good water, the salt content seldom rising above 25 parts per 100,000. The wells in the white soils south of Fresno occasionally carry 100 parts of salt per 100,000. Very few of the well waters contain much sodium carbonate, but most of the wells contain considerable bicarbonates in solution.

The alkali of the soil contains as a rule sodium carbonate, and where this is present it constitutes anywhere up to 90 per cent of the total salts. The bicarbonates are also present in quite noticeable amounts, constituting about 24 per cent of the total weight of salts where carbonates are present and about 5 or 6 per cent where carbonates are not present. Most of the soils which contain no carbonates carry very considerable quantities of calcium chloride, which occurs at times to the extent of 50 per cent of the total weight of salts. In such soils magnesium chloride is also quite abundant, sometimes constituting 30 per cent of the total weight of salt. In nearly all cases sodium chloride is very abundant, and occasionally sodium sulphate enters as an important constituent. Sodium carbonate is almost universally present in greater or lesser amounts, and as this is so very harmful to vegetation it makes the problem more serious. On the whole, the area impregnated with sufficient alkali to be harmful to vegetation is very

much smaller than was supposed to be the case, and is confined mainly to certain types of soils and to the low-lying poorly drained areas in the southern part of the district. About 10 per cent of the area of the whole district contains at the present time too much salt for crop production; about 6½ per cent contains so much salt as to make cultivation more or less risky, while about 84 per cent is free from injurious amounts of alkali. Mr. Means discusses in his report methods for the prevention of the rise of alkali and for the reclamation of the alkali lands. He also dwells at length upon the condition of agriculture and the splendid success which has attended the development of the agricultural interests of the locality as a whole.

SANTA ANA AREA, CALIFORNIA.

The area surveyed includes much of the district tributary to Santa Ana and Anaheim, comprising about 300 square miles and extending from the foothills to the Pacific Ocean. The main portion of the district is a vast delta plain formed by the Santa Ana River. There appear to be three important physiographic features—the foothills proper, upon which it is difficult and costly to get irrigation water, which are used for grazing purposes where water is not available and for citrus fruits where the lands can be irrigated; a high-lying portion of the delta plain above the 70-foot contour, which is the principal agricultural land for citrus fruits and nut trees; below this 70-foot contour are lowlands adapted either to alfalfa or natural pasturage and to important special industries of celery and truck growing. Fruit industry is seldom found upon this low-lying portion.

The Fresno sand, a typical truck soil, formed of a coarse, loose, incoherent sand, 6 feet or more in depth, naturally free from alkali, covers about 37 per cent of the district surveyed. This is adapted to stone fruits and truck when irrigated, and is occasionally dry farmed to wheat. The Fullerton sandy adobe covers the next largest area, aggregating nearly 18 per cent of the district. It is underlaid at a depth of about 5 feet by compact sand or sandstone. This is found principally in the foothills, and is often dry farmed to wheat. In the extension of the soil into the valley it is used to some extent for citrus fruits under irrigation. The other much more important agricultural soils are found in much smaller areas, none of them constituting over 10 per cent of the district surveyed; but these are extremely important soils commercially under the intensive cultivation of citrus fruits, stone fruits, and nuts, or in the low-lying portions to truck crops. Mr. Holmes dwells at length upon the character of the soils, their relation to crops, and their general agricultural value.

The soils as a rule are well drained, and owing to the small amount of water available for irrigation, and the great care taken in the construction of canals and laterals to prevent seepage, there are comparatively few areas affected by alkali, and these are mainly in the low-

lying lands which are not at present of much agricultural importance. So valuable is water in this area that of 100 miles of irrigation ditches, operated by one of the canal companies, 26 miles are cemented at the sides and bottom at a cost of from 25 cents to $1.50 per foot, and it is the object of the company to eventually protect the entire system of ditches in this way to reduce the loss from seepage to a minimum. The irrigation of the lowlands is altogether from artesian wells. Alkali soils are very rarely found at elevations exceeding 100 feet, but are confined almost exclusively to the low-lying portions of the delta plain, where subirrigation has brought them to the surface. The salts have nearly all accumulated in the upper 2 or 3 feet of soil.

The alkali consists principally of sodium chloride and sodium sulphate, magnesium sulphate being occasionally present in considerable quantities. Sodium carbonate is very seldom found in any appreciable quantity.

Mr. Holmes describes in considerable detail the agricultural conditions of the district.

LABORATORY INVESTIGATIONS, SUPPLEMENTAL TO THE FIELD OPERATIONS.

PHYSICAL PROPERTIES OF SOILS.

The laboratories have contributed, as in previous years, to the work of the field parties in the analysis of samples sent in and in the investigation of certain problems encountered in the field which had to be investigated by laboratory methods. Mr. Briggs contributes an important paper on the "Investigations on the physical properties of soils." It is found that the laboratory method of testing the capillary power of soils by the rise of water in a column of dry soil does not give the height at which capillary action operates under the conditions in the field when the soil contains more or less moisture. The difference in the two methods is so marked that laboratory experiments with dry soils fail entirely in giving a qualitative measurement of the extent of capillary movement in the same soil in a moist state. In the sea-island cotton soils, for example, the capillary rise in the moist soil is over four and one-half times that taking place in the dry soil. Other investigations are in progress to determine whether a constant ratio exists between the two determinations for any soil. If no relation between the two determinations can be established, the measurements of the capillary rise of water in dry soils which have been so extensively made in the past are of little or no value in interpreting the relation of a soil to water under field conditions. This power of soils to transport water through capillary action is particularly important in the consideration of alkali problems. He has also further investigated the influence of dissolved salts on the capillary

rise of soil waters, and finds a marked effect of sodium carbonate in apparently facilitating the rise of water, at least in dry soils. He attributes this, in part, at any rate, to the solvent action of the carbonate on any grease which may be present on the surface of the grains, which would consequently present a cleaner surface to the ascending water.

Considerable difficulty has been experienced in the use of chemical methods in the field for the alkali work, due to the presence of suspended clay particles in the soil extracts that were made. A very efficient filter has been devised, to be carried as part of the equipment of the field parties, consisting of a Chamberlain-Pasteur tube with a pump for filtering under pressure, so that sufficient quantity of liquid perfectly free from suspended matter of any kind can be obtained in the field. This has been a valuable addition to the equipment of our field parties.

It has been found that if specially purified quartz sand be left exposed to the air it will take up by absorption 200 times as much carbon dioxide as would be contained in a volume of free air corresponding to the total volume of the interstitial space in the soil. The atmosphere within ordinary soils contains from 30 to 200 times the amount of carbon dioxide found in the free atmosphere above the soil, so that the amount of carbon dioxide actually absorbed and held by the soil grains must be enormous. Soils undoubtedly differ in their property of holding carbon dioxide, but the amount in any case is probably very great.

This property of the soil to absorb large quantities of carbon dioxide has unquestionably an important bearing upon the sodium carbonate, constituting the worst form of alkali. When sodium, lime, or magnesium carbonates are brought into the presence of carbon dioxide under normal conditions they are very largely converted into the bicarbonate. In the case of the lime and magnesium salts this very largely increases the solubility of the material. In the case of sodium carbonate, after being converted into the bicarbonate, it is much less harmful to plants. Investigations in this laboratory by Mr. Kearney show that while the sodium carbonate is one of the most harmful of the salts, the sodium bicarbonate is one of the least harmful. It has already been noted that bicarbonates form a very large proportion of the soluble salts of the Sevier River Valley district in Utah, where the carbonates are rarely found in measurable quantities. In the Fresno area, while there are considerable quantities of bicarbonates, there are also large quantities of carbonates present. Anything that will increase the amount of free carbon dioxide in the soil, such as decaying organic matter, should have a tendency to convert the carbonate into the bicarbonate, and so decrease the danger from the sodium salts. These matters are all being investigated further in this laboratory, as their economic importance fully justifies a prolonged and thorough investigation.

APPLICATION OF THE THEORY OF SOLUTION TO THE STUDY OF SOILS.

Under this head, Dr. Cameron gives a second contribution to this important matter, developing the subject much further than in his paper published in the last annual report. He discusses particularly the rôle of iron, calcium, hydrous silicates, carbon dioxide, and organic matters in the soil. While this is treated in a technical manner, and while much of it is speculative in character, it throws a very important light upon the constitution of the soil components and the functions of the nutrient substances, which is calculated to give us a much clearer conception of the very difficult subject of the chemistry of soils than has been possible from the previous conceptions and writings of agricultural chemists.

In Mr. Gardner's work in the Sevier River Valley it was found that there were very large quantities of bicarbonates present with traces of normal carbonates, except where solutions of the soil were allowed to stand in the open air, when they became gradually alkaline. This was so surprising a matter that the question was referred to the laboratory, and Dr. Cameron and Mr. Briggs have investigated the subject of the equilibrium between carbonates and bicarbonates in the soil, for it makes a very important economic difference whether the sodium carbonate is present as the normal carbonate as it occurs in the Fresno area, or as bicarbonate as it occurs in the Sevier River Valley area. Sodium bicarbonate had formerly been looked upon as a very instable compound, but these investigations show that it is exceedingly stable and persistent under given conditions. The wonder is that under conditions presumably existing in the soil, about which we know very little positively, the sodium carbonate is not all and always converted into the bicarbonate. When sodium carbonate in solution is exposed for some time to the air, until it comes into equilibrium, more or less of it will be converted into the bicarbonate, the amount depending upon the temperature and upon the concentration of the solution. At a temperature of 100° C., or when the solution is boiled, all the sodium is combined as normal carbonate. In an experiment conducted at a temperature of 25° C., it was found that when exposed to the ordinary air in a solution containing about 2.9 grams of sodium per liter (originally added as sodium carbonate) about an equal amount was found as normal carbonate and as bicarbonate. Under the same conditions a solution containing 9 grams of sodium per liter contained 63 per cent of the base as normal carbonate, and it required 45 grams of sodium per liter to raise this to 65 per cent when equilibrium had been established. In very dilute solutions the sodium was practically all present as bicarbonate. It will be remembered, however, that the proportion of carbon dioxide in the soil atmosphere is very much greater than in free air and, as Mr. Briggs has shown, the amount of carbon dioxide absorbed by the soil grains is very large; so that the conditions in the Sevier River Valley,

where the sodium is practically all present as the bicarbonate, would appear reasonable both on account of the absorbed carbon dioxide in the soil and the small amount of the salt present. The bicarbonate is a comparatively harmless salt, while the normal carbonate is extremely pernicious.

While these investigations throw a most important light upon the equilibrium between sodium carbonate and bicarbonate when exposed to the ordinary atmosphere, they are not yet sufficiently developed to explain the cause of the differences observed between important areas, which may depend upon soil conditions of which we have at present little knowledge or appreciation. It will be necessary, for instance, to study the relation of the composition of the atmosphere in the soil to other existing conditions. The investigations are extremely suggestive, however, and should lead to a very much more intimate knowledge of the field conditions and methods of treating the black alkali problem than is now possessed.

A matter of very great interest in the study of irrigation and drainage waters of the West is the enormous quantities of gypsum obtained upon evaporating these waters to dryness and expressed as gypsum in the chemical analysis. As gypsum is commonly looked upon as an antidote to sodium carbonate and as a corrective of many unfavorable soil conditions, this matter also was referred to the laboratories for investigation. It was found that the increased solubility was due to the other salts present, particularly to the sodium chloride. When calcium sulphate is mixed with sodium chloride, a certain amount of calcium chloride is formed which is very soluble, together with sodium sulphate, both of which are very much more soluble than the calcium sulphate. Very much more calcium therefore goes into solution, but there is probably little or no more calcium sulphate as such in solution than would be soluble in pure water. On evaporating the water, however, the calcium would be again deposited as calcium sulphate. In an experiment made in this laboratory at a temperature of 25° C., it was found that one liter of pure water dissolved 2.7 grams of gypsum, equivalent to 2.1 grams of calcium sulphate. With 10 grams of sodium chloride dissolved in the water at the same temperature, 3.5 grams of calcium sulphate or 4.4 grams of gypsum would be dissolved. The solubility increases until, with 135 grams of sodium chloride, 7.5 grams of calcium sulphate or 9.3 grams of gypsum would dissolve, or nearly three and one-half times the quantity which would dissolve in a liter of pure water. These investigations on the solubility of different salts and the effect of one or more salts upon the solubility of another have an important bearing on the formation and transportation of alkali in the soil. The effect of these salts on the solubility of other salts is not always to increase the solubility, as with certain mixtures the solubility is decreased. These matters are fully discussed in Dr. Cameron's paper.

So important is this effect of one salt upon the solubility of another, and upon the products of mixtures of certain salts, that Dr. Cameron has proposed a classification of alkali soils, based upon the composition of the irrigation and seepage waters and upon the constitution of the soils. The peculiarity of the Pecos type is the reaction between the sodium chloride and the gypsum in the soil, giving rise upon the application of water to the formation of calcium chloride, which, on account of its extreme solubility, leaches out or accumulates in local areas, and of sodium sulphate which may form a large proportion of the salts present. The peculiarity of the Fresno type is the action of sodium chloride upon calcium carbonate in the presence of carbon dioxide, yielding calcium chloride and sodium bicarbonate, the latter changing in part to the normal carbonate or black alkali. The peculiarity of the Salt Lake type prevailing in the Salt Lake Valley, Utah, is the reaction between the sodium chloride, gypsum, and calcium carbonate in the soil. As a result of this mixture, there will be formed calcium chloride (which for reasons mentioned above is found only in local spots) sodium sulphate, and sodium carbonate or bicarbonate. The gypsum present will, however, tend to reduce the amount of sodium carbonate formed as well as the amount of sodium bicarbonate, and the principal product will be sodium sulphate. The peculiarity of the Billings type, found in the Yellowstone Valley, is the presence of soluble sulphates, probably derived from the oxidation of iron sulphides and the effect of the hydrolized free sulphuric acid on the other mineral components of the soil. It is believed that this classification will materially aid our field parties in their investigations, and will show the practical man, who understands the composition and conditions of the soil, about what to expect upon the application of water to new areas.

Dr. Cameron calls attention to the occasional occurrence of alkali in humid regions, which it is believed deserves more attention at the hand of the soil chemist, as it seems quite likely that there are local accumulations of salts which may be harmful to vegetation and may explain the cause of the relation of soils to crops in some cases—causes which have heretofore escaped the attention of the soil chemist. In addition to what Dr. Cameron has to say on this subject, it would be interesting to call attention to another instance which is of very marked economic importance. In the study of the die-back disease of the orange no evidence has been found that the trouble was caused by fungus or bacteria, and it was suspected that the seat of the trouble was in the soil. Careful examination of a large number of samples sent to the laboratory years ago failed to reveal any peculiarity in the chemical composition, either as to the kind or amount of material present.

A personal examination of the soils in the field revealed the presence (in the soil where die-back occurs) of a dark-colored substance, which

usually is in layers at some distance below the surface, the thickness of these strata often being only about one-tenth of an inch, and which might be entirely overlooked in a sample collected and sent to the laboratory. More recently this same substance has been found in such quantities that it is recognized in the laboratory samples of soil from a large area near Fort Meade, Fla., known as the "Indian deadening," which tradition says was cursed by some of the Indian medicine men as a retribution on some of their enemies. However this may be, the area has always been considered unproductive, and few successful efforts have been made to farm the land. Samples containing the same substance have been received from areas in James Island, South Carolina, where certain diseases occur in the sea-island cotton which have some relation to the die-back disease of the orange. Here again the amount of the material is so large that it was easily recognized in the samples sent to the laboratory. This material appears to be largely of organic origin, as the soil has a very high resistance in the electrolytic cell. It is distinctly acid to test-paper when in a fresh condition, but loses this acidity largely on drying for some time and again being moistened. It has the peculiar property, also, of adhering very closely to the soil grains, and, upon long standing in contact with water and after repeatedly being shaken up, the grains will give a strong red color to litmus while the water above the grains will be quite neutral. The cause of the accumulation of this material is not understood, nor has its composition or exact nature been determined. The subject is mentioned here to show there may be local accumulations of material in the soil which may not be revealed in the ordinary chemical examination of a laboratory sample, and which can only be discovered by a very careful examination of the soil in the field.

The field methods for the estimation of carbonates, bicarbonates, and chlorides have been still further improved and are now in very satisfactory shape. No convenient method has yet been devised for the estimation of sulphates in the field.

There has been a very general impression in the West that certain plants favor the formation of sodium carbonate or black alkali. Dr. Cameron has made quite a thorough examination of this and finds strong evidence to show that certain plants are able and actually do take up considerable quantities of sodium chloride, retain the sodium in organic combination, and eliminate the chlorine either before it is taken up by the roots or as an exudation or in a form which we recognize as odor. After getting rid of the chlorine, the sodium will be left in the form of sodium carbonate in the decay and oxidation of the plant. It seems probable that this is quite general, but the effect on the soil would only be noticed in arid regions.

Attention was called by Mr. Means to the fact that certain grasses were growing in areas very strongly impregnated with black alkali in the Fresno district, and it was a further interesting fact that these

grasses seem to be quite acid to the taste and show an acid reaction when digested in water. At times the plants seem to be covered with an acid exudation. Whether this is due to some function of the plant giving it the power to neutralize the sodium carbonate as it comes in contact with the plant body has not been determined, but the subject is a matter of very considerable interest, and investigations will be continued.

EFFECT OF SOLUTIONS OF CERTAIN SALTS ON PLANT GROWTH.

A number of important economic problems have been encountered by the field parties in the survey of the alkali soils of the West for which no satisfactory explanation could be found in the literature. For example, little is known of the relative effect on plant growth or on the distribution of crops of different mixtures of salts encountered in the districts where different types of alkali prevail. The unexpected occurrence of large quantities of sodium bicarbonate in the Fresno, and especially in the Utah, areas made it important to determine the effect of this salt upon plant growth, an effect which has hitherto never been specifically determined. The marked influence of the application of gypsum to alkali lands has never been clearly understood nor fully appreciated. Similar facts made it appear desirable to conduct a careful and thorough investigation into the subject of the effect of solutions of various salts commonly encountered in alkali soils upon the growth of plants.

Through cooperation with the Division of Vegetable Physiology and Pathology, Mr. Thomas H. Kearney has done some very important preliminary work in this line, the full results of which will be published in a separate bulletin, but an outline of which will be given at this place, as they have an important bearing upon the field conditions under which soils and the plants they support are found, and will probably have an important influence upon the treatment of the subject of alkali lands by our field parties in their future reports.

The laboratory method used by Mr. Kearney consisted in germinating white lupine or alfalfa seeds and suspending them with their radicals immersed in a solution of the salt or mixture of salts, the influence of which upon the plant it was desired to test, and observing the effect upon the tip of the radical after twenty-four or forty-eight hours. If at the end of this time the radical was still in a healthy growing condition another set of plants was immersed in a solution of the same salt or salts with a higher concentration, or, if the radical showed signs of death, in solutions of a weaker concentration. By varying the concentration in this way and by observing the effect upon a large number of seedlings it was possible to closely approximate the limit of endurance of the young seedlings to the salts used

In nearly all cases a variation was noted in the resistance of the

individual plants to the stronger solutions, some individuals being apparently unaffected in solutions of such concentration that the majority of the plants were killed. This is an important point probably, as indicating the possibility of selecting and breeding alkali-resisting plants in the laboratory. It is noteworthy that the sharpest results of this kind were obtained when dealing with solutions of carbonates and bicarbonates.

The principal salts experimented with were magnesium sulphate, magnesium chloride, sodium carbonate, sodium sulphate, sodium chloride, sodium bicarbonate, calcium chloride, calcium carbonate, and calcium sulphate. The salts were used alone in pure water or in mixtures of two or more salts dissolved in water. In no case was there any plant food present in the water other than the salts to be experimented with. It is not to be supposed that the seedlings would have lived very long in such a one-sided ration, but it was assumed that the seedlings themselves contained enough food to support them for the period involved, and the purpose of the experiment was to determine the concentration in which the roots were just able to perform their proper functions, beyond which the concentration could not be carried without killing the plant within twenty-four or forty-eight hours. Under these conditions it was found that where the individual salts were used alone in distilled water the plants could stand only a very small quantity of each, the limit being given in the following for each salt in parts per 100,000 of water:

	Parts per 100,000 of water.
Magnesium sulphate	7
Magnesium chloride	12
Sodium carbonate	26
Sodium sulphate	60
Sodium chloride	116
Sodium bicarbonate	167
Calcium chloride	1,377

The limits given in the above are for white lupine. Alfalfa seems to be rather more sensitive to each of the salts, but the relative order is about the same.

It is an interesting fact that the mixture of any of these salts is less harmful than where either of the salts is present alone in the distilled water. Generally the limit of endurance for the more toxic salts, such as magnesium sulphate, is raised from 8 to 20 times by the addition of some of the other salts, which in themselves are more harmful than the mixture.

The most surprising results, however, were obtained when the solution was saturated with respect to calcium sulphate and calcium carbonate, both, under ordinary conditions, only slightly soluble in water. But both have a most remarkable influence on the toxic effect of other more soluble salts. The following table gives the results of

Mr. Kearney's experiments along this line, showing that the magnesium sulphate, which by itself is the most fatal of all the salts tried, is the least harmful in the presence of calcium sulphate and calcium carbonate:

Limits of salts for lupine and alfalfa when in the presence of calcium sulphate and calcium carbonate.

Salt.	Limit for lupine in parts per 100,000.	Limit for alfalfa in parts per 100,000.
Magnesium sulphate	2,240	1,960
Sodium sulphate	2,160	2,160
Sodium chloride	1,160	1,160
Magnesium chloride	960	960
Sodium bicarbonate	417	667
Sodium carbonate	.56	104

It appears from this that the calcium salts, although only slightly soluble, have a remarkable effect on salts present in alkali soils, and as all of these alkali soils almost invariably contain large quantities of calcium carbonate or calcium sulphate, or both, it is probable that the soil solutions are often nearly saturated with respect to a calcium salt, so that the sodium and magnesium salts are usually protected in this way and are as harmless as it is possible for them to be. These results suggest an explanation for certain conditions which before appeared difficult to understand. It has been suspected that the sterility of certain soils in the Eastern States is due to the fact that the magnesium is present in larger amounts than the lime, and that such condition was unfavorable to plant growth. The actual amount of magnesium in some of these soils is extremely small, yet larger than the amount of lime. In some of the alkali soils of the West, notably in the Yellowstone Valley, the magnesium sulphate forms one of the chief constituents of the alkali, the mixture of salts forming as much as 0.5 per cent or 0.6 per cent of the weight of soil without injury to crops. Such soils, however, always contain large quantities of gypsum, and it is probable that this fact accounts for the immunity that plants have in the presence of large quantities of magnesium salts in this locality.

The lime salts are not only difficultly soluble, but as a rule, they go into solution slowly, because they are in large amorphous or crystalline masses. Some irrigation waters of the West carry large quantities of lime sulphate in solution, owing to the solvent action of the sodium chlorides or other salts. When these waters are evaporated to dryness and the residue mixed with a quantity of water equal in volume to that originally taken, the calcium sulphate dissolves very slowly, requiring often thirty or forty days to be completely redissolved. Where the irrigation waters of the West pass over soils containing sodium chloride and gypsum they may readily take up their

share of the soluble sodium salts, but be far from saturated as regards the calcium sulphate. In considering the analysis of an irrigation water our soil parties will be careful to consider the ratio between the calcium salts and the other salts, as this may throw some important light upon the safety of the water for irrigation purposes. Obviously the nature of the soil upon which the water is to be used will enter as a factor in this consideration, the presence of gypsum or calcium carbonate or calcium and magnesium carbonate in the soil being no less important than the mineral substances in the water.

This is, however, an extremely difficult matter to handle intelligently in the present state of our knowledge. And the idea that finds favor in some quarters that there is a definite ratio between the calcium and any other base—for instance, magnesium—which may be in the solution and which is best adapted to the growth of the particular plant, is to be viewed with caution. The relative mutual effects on the dissociation and number of ions must be considered, which it is exceedingly difficult to do. Moreover, it is certain that while the anions are not as important as the kathions in determining the value of a nutrient solution, yet their influence is very considerable and can not be neglected. As an illustration of this, Kearney found that 12 parts per 100,000 of magnesium chloride alone was the fatal limit for lupine. But in contact with the solid calcium sulphate the limit was raised to 960 parts per 100,000, or about 80 times. In this solution the solubility determinations of Cameron and Seidell, recorded elsewhere in this report, show that there were present about 450 parts of calcium sulphate, or that the solution contained in approximate figures 0.105 reacting weights per liter of magnesium to 0.034 reacting weights of calcium. Kearney's results show that in the presence of calcium chloride a toxic limit was reached in a magnesium chloride solution containing 0.050 reacting weights of magnesium and 0.054 reacting weights of calcium. In a calcium chloride solution alone the fatal limit was reached with about 0.125 reacting weights per liter of calcium.

A more direct comparison can be made with Kearney's results on sodium chloride solutions. In the presence of a solid excess of calcium sulphate the toxic limit was obtained in a solution containing about 0.2 reacting weights of sodium, and, according to Cameron's solubility determinations, 0.027 reacting weights of calcium. With calcium chloride in the solution instead of calcium sulphate the limit was reached as before with 0.2 reacting weights per liter of sodium, but 0.1 reacting weight of calcium. Therefore, calcium in the form of the sulphate is apparently much more efficacious than when it is in the form of the chloride. A more rational way of looking at the matter, however, is that the chlorion is more inimical to plant growth than the sulphion. In fact, all Mr. Kearney's work bearing on this point leads to the same conclusion; and that in turn the sulphion is more toxic than the carbonic acid ion, the very toxic effect of normal car-

bonate being due in large measure to the hydroxyl ion, which ranks next to the hydrogen ion among anions in their toxic effect.

It should be emphasized that these results are but preliminary, and that much further work is imperatively needed along this line. Enough has been accomplished to show its great importance for economic purposes, and to enable at least qualitative judgments to be formed on many points which hitherto have proved baffling and uncertain.

TOBACCO INVESTIGATIONS.

Tobacco investigations have been carried on in two lines during the year; one was an investigation of the possibility of producing a desirable wrapper leaf of the Sumatra style desired by the tobacco trade as a substitute or improvement of the present style of Connecticut leaf; the other was the possibilities of fermenting the Pennsylvania leaf in such a way as to prevent enormous losses by black rot and to improve the quality of the leaf. This was preliminary to the introduction of a new type of tobacco in the Pennsylvania area to improve the quality of the output from that important cigar-tobacco district.

The methods and results of the introduction of Sumatra tobacco grown under shade in the Connecticut Valley is described at length by Mr. Floyd in his report, and has given so much encouragement and so much promise that it has been decided to continue the work and to push the introduction of this valuable leaf to meet the competition from the imported leaf. The importance of this subject has been dwelt upon in the annual report of the chief of the Division of Soils to the Secretary of Agriculture, and is so clearly set forth in Mr. Floyd's report that further comment in this place is considered unnecessary.

The real purpose of the operations in Pennsylvania is to follow up the results of the soil mapping with an attempt to improve the quality of the leaf grown there or to introduce the Havana tobacco, with such modifications in the methods of cultivation and fermentation as will insure a more desirable leaf with finer aroma than is possessed by the present style of Pennsylvania leaf. Incidentally, however, it was desired to see if the quality of the present Pennsylvania leaf could not be improved by a different method of fermentation, and to see if black rot could not be prevented at the same time. Investigations have convinced us beyond doubt that the style of the leaf will have to be entirely changed either by breeding or the introduction of new varieties. The method of fermentation adopted, however, has almost entirely stopped the loss from black rot. The germs of the fungus which causes this trouble come from the unsanitary condition of the curing shed and the damp cellars where the tobacco is hung by farmers to bring it to proper order for stripping the leaves from the stalk. This source of trouble could and should be entirely

removed by proper sanitary conditions, by thorough ventilation of the cellars and sheds before the crop is harvested, by the removal of all decaying vegetation from the inside as well as from the outside of the building, and the proper application of lime or sulphur to the floors and walls of the buildings before the tobacco is hung. The latest reports received from the Pennsylvania area indicate that at least 4,000,000 pounds of the 1900 crop of tobacco will be fermented in Lancaster County by the bulk method, with no loss from black rot except in one bulk—one of the first done under our direction and before we were entirely familiar with the character of the Pennsylvania leaf. This one bulk was almost a total loss, but has proved to be a valuable lesson in indicating the character of the leaf and the precautions necessary to be observed in the fermentation to prevent the development of the dreaded black rot, which causes a loss annually of hundreds of thousands of dollars in that locality alone.

A SOIL SURVEY AROUND LANCASTER, PA.

By CLARENCE W. DORSEY.

INTRODUCTION.

During the field season of 1900 several months were spent in making a detailed soil survey of about 270 square miles in the principal tobacco-growing district of Lancaster County, Pa. In 1899, a large area in the Connecticut Valley in Connecticut and Massachusetts was surveyed, and maps were prepared showing the distribution of the various soils where the different types of cigar-wrapper leaf tobacco are grown. Lancaster County was selected as the oldest and one of the most important cigar-filler tobacco districts of Pennsylvania, and indeed of the United States.

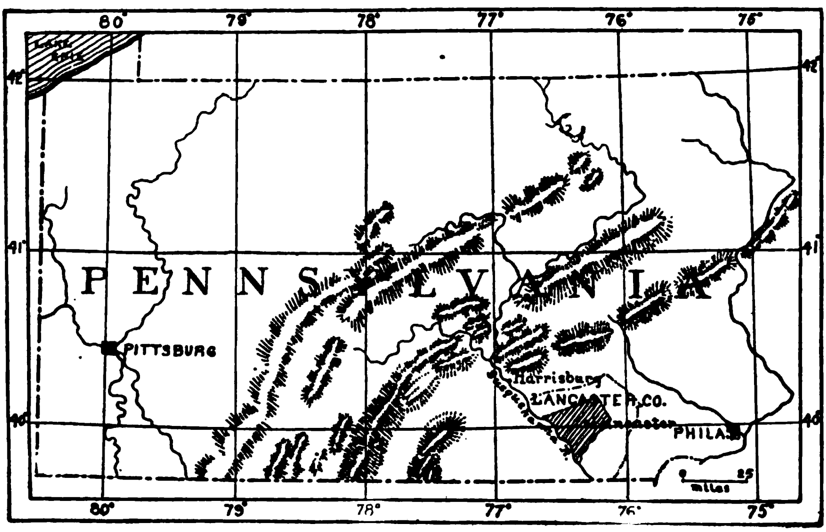


FIG. 1.—Sketch map of Pennsylvania, showing position of Lancaster County and area surveyed.

Lancaster County is situated in the extreme southeastern part of Pennsylvania. The Susquehanna River flows along the entire western border, while the southern part of the county touches Cecil County, Md. It is one of the large counties of Pennsylvania, its area being, approximately, 970 square miles. The fortieth parallel passes through the south-central part, and the greater portion lies between 76° and 76° 30″ west longitude. It was early settled, and for a long time has ranked as the foremost agricultural county of the State.

That part which was surveyed lies in the west-central portion of the

county (see fig. 1), with the Susquehanna River along the western border, Lancaster, the county seat, being in the central part of the area.

TOPOGRAPHY.

The beautifully diversified surface of the country is the result of the unequal weathering and erosion of the rocks which are found there. Rocks which weather rapidly, such as limestones, have formed the broad rolling valleys which constitute so pleasant a feature of the landscape. Other rocks, composed of materials which have more successfully resisted the wearing down processes of erosion, now form prominent ridges running across the county and the more hilly portions found along Pequea and Conestoga creeks. Generally speaking, the surface of the country consists of wide valleys, ranging in elevation from 350 feet to 400 feet above sea level, broken by long ridges which rise from 100 to 250 feet above the general valley level.

The broad limestone valley, in the center of which Lancaster is located, is broken by a prominent sandstone ridge which traverses the area. This rises abruptly from the river just north of Columbia, and continues in an easterly direction as a prominent ridge until about 5 miles northwest of Lancaster, where it becomes broken and appears only as scattered hills. Another prominent ridge, about 1 mile south of Lititz, rises considerably above the limestone valley and continues unbroken across the northern part of the entire area.

South of Columbia are prominent ridges extending in an easterly direction until they merge into the sandstone ridge described above. In the southern part of Conestoga and Pequea townships are hilly stretches of country, which rise to an elevation of probably 500 feet above sea level.

The Susquehanna River traverses the entire western border of the area surveyed. It varies in width from one-half to slightly over one and one-fourth miles. Where the river comes in contact with limestone rocks the country slopes gradually back to the broad valleys; where the sandstones and the older crystalline rocks are found the river has high, steep, heavily wooded banks, which rise to a considerable elevation. The entire area is well watered by a great number of small streams. The main streams, which carry away the greater part of the rainfall, are the Conestoga, Little Conestoga, Pequea, and Chiquesalunga. All of these creeks flow in a southwesterly direction and empty into the Susquehanna. The various streams furnish abundant water power, which is utilized to a great extent by numerous mills for grinding wheat and corn. The streams are dammed at frequent intervals, and practically all of the flour and paper mills in the county are run by water power. Nearly all of the mills are old, some of them having done service for more than a century, and, judging from their substantial appearance, are fully capable of another century's service before their day of usefulness is ended.

GEOLOGY.

In Lancaster County the soils are, with but few exceptions, the result of the disintegration and decay of the various rocks which occur there, so that a close connection is seen between the soils and rocks of the country. It is found that the limestone valleys are always characterized by soils which have certain features in common, while the soils of the sandstone and shale ridges always partake largely of the nature of the rocks from which they are derived.

The rock formations belong to four great geologic divisions. The first division covers the old metamorphic series of rocks, comprising in the area surveyed the chlorite and mica-schists of the lower townships along the Pequea and Conestoga creeks. Comparatively little is known of the origin of these rocks, as the changes which have taken place in them, caused by the alteration processes through which they have passed, are complex and manifold.

The second group of rocks found in the county embraces the limestones and sandstones, sedimentary rocks whose origin and age are definitely known. It is from these, and especially the former, that the richest agricultural lands are derived. These rocks are all sedimentary deposits which have also undergone changes due to the processes of metamorphism since they were deposited, but the changes have not been so marked as in the rocks just referred to.

The third great division is represented by the steep shale hills which traverse the area several miles north of Lancaster. The belts of igneous trap rocks or "iron stones" also belong to this series of formations.

The fourth class of rocks found in the area represents the series of gravels and sands found as terraces along the Susquehanna River and a few of the larger streams. These deposits belong to a much later geological period than any of the above. These four classes of rock deposits are commonly referred to by geologists, naming them in the order given above, as Archæan, Paleozoic, Mesozoic, and Cenozoic, these names referring to the character of animal and plant life which existed at the time the rocks were formed, except the Archæan, which is characterized by the absence of either plant or animal life.

The various rock formations of this portion of Lancaster County furnish many valuable and useful deposits. The Paleozoic limestone beds furnish large quantities of fine stone suitable for building purposes, material for roadways, ballast for railroads, and material well adapted for making lime. There are small deposits of marble in some parts of the county, but the quality and extent of the deposits have never been fully investigated. Sandstone or quartzite furnishes some building stone, and when crushed makes a fine sand suitable for the manufacture of glass. The terraces along the Susquehanna furnish good building sand and gravel for road ballast. Formerly there were

several rich iron mines, but of late years many of these have ceased to be operated. The most extensive iron mines now in operation are situated near Silverspring.

CLIMATE.

During the growing season it is much hotter in Lancaster County than it is in the northern and western parts of the State. This is due to the fact that the average elevation above sea level of Lancaster County is much less than in the northern and northwestern parts of the State. The proximity to large bodies of water also exerts considerable influence.

The following table, published in the Annual Report of the Pennsylvania State College for 1898–99, shows the mean annual temperature and rainfall for the growing season:

Mean annual temperature and rainfall.

Month.	Mount Joy.		Ephrata.	Lancaster.
	Mean temperature (16 years).	Mean rainfall (11 years).	Mean rainfall (8 years).	Mean rainfall (4 years).
	°F.	Inches.	Inches.	Inches.
April	52	3.33	4.38	4.22
May	63	3.74	4.68	3.11
June	73	3.84	4.58	3.75
July	77	3.25	3.96	2.83
August	74	4.38	5.61	3.85

The mean maximum temperatures for this section of Pennsylvania are: April, 61°; May, 71°; June, 81°; July, 84°; and August, 81°. The mean minimum temperatures are: April, 40°; May, 49°; June, 60°; July, 64°; and August, 61.° The mean daily ranges of temperature are: April, 21°; May, 22°; June, 22°; July 21°; and August, 22°. The mean annual rainfall is 44 inches. The southern part of the county is said to have a slightly greater amount of rainfall than the annual average just given, but figures are lacking to substantiate this statement. The autumns are always late in Lancaster County and it is said that tobacco planted as late as July is seldom caught by frosts, which rarely occur before October.

HISTORY AND EARLY AGRICULTURE.

According to the old histories and records, when Lancaster County was first settled, in 1709, it presented an appearance quite unlike the present. The few scattered tribes of Indians living in this section at the time were not the original tribes, but remnants of tribes that had been driven out of Maryland, Virginia, and the Carolinas. They lived by hunting and fishing and by carrying on a primitive system of agriculture, the squaws raising small crops of corn and beans. The

methods of agriculture were primitive. They first girdled the trees and burned them, then scratched the ground with crooked sticks and planted their crops; later they cultivated the growing crops with shells and sharp stones. In the fall the cornstalks and weeds were scraped together and burned. This killed all the young saplings except the hardier scrub oaks. These latter, after being repeatedly burned, formed thick, knotted clumps of roots. Such areas the early settlers called "grubensland." At the time this section was settled there were several of these Indian fields, one being just west of Lititz.

With the exception of the few scattered Indian fields and occasional swamps and meadows, the country was densely forested. This was especially the case in the limestone valley. On the sandstone ridges the timber was not quite so abundant. On the heavy limestone soils the forest consisted of a thick growth of ash, elm, hickory, walnut, and several varieties of oaks, all being indicative of a deep, rich soil. On the sandstone and slate ridges the forest trees were not so large, but were tougher and included more varieties. These ridges were the native home of the chestnut.

The Mennonites, who emigrated from Switzerland and the Palatinate, were the first white settlers in what is now Lancaster County. They came in 1709, and advanced as far as the Conestoga. Shortly after them followed the French Huguenots, who settled in the Pequea Valley, emigrating from the departments of Alsace-Lorraine. The Huguenots were in turn followed by the Scotch-Irish, who settled on Chickies Creek in 1715. Other settlers followed in rapid succession, including the Welsh Episcopalians, Quakers, Dunkards, and Lutherans.

The Scotch-Irish settled in the more hilly portions, because the lighter timber of the stony ridges was more easily cleared and the country somewhat resembled their native homes. The Swiss and Germans, however, who keenly appreciated the value of wood from the severity of the forest laws in Europe, selected for their farms the richest meadows and heaviest tracts of timber in the limestone valleys, reasoning that where the timber was heaviest there the soil must be richest. There are some, however, who maintain that the Germans and Swiss, the noncombatants, were assigned to the valleys, while the Scotch-Irish, naturally fighters, were encouraged to settle on the hills, where they might first come in contact with the Indians or other enemies.

Much has been written of the hardships and struggles of the early settlers. They cleared small tracts of land with great labor, and portions of the natural meadows were staked off. Crops of oats, corn, barley, and buckwheat were cultivated for summer crops, and rye was the main winter crop. Spelt was grown in place of wheat, as the latter was considered too delicate to be grown in this section. Flax and hemp were soon introduced.

As the natural meadows were the only places where hay was grown, these were enlarged by damming the small streams and flooding the meadows at certain times. In the early title deeds to the farms the rights to water for irrigation purposes were clearly set forth. The use and control of the stream were given to the owners of the several tracts of meadow land for a certain number of days in each week. In about the year 1800 timothy and red clover were introduced, and it was found that these crops could be grown on the uplands, so the meadows were no longer so necessary to furnish the hay crops. Remnants of the old dams can still be seen along many of the small streams.

A few years later wheat was introduced, which gradually superseded spelt and barley as grain crops; improved machinery for use in cultivating and harvesting crops were introduced; large Swisser barns and substantial limestone houses were built, and the country began to assume much its present appearance.

AGRICULTURAL CONDITIONS AND STATISTICS.

Lancaster County is preeminently an agricultural county. It is a county of well-kept, carefully cultivated farms, which attest the thrift and industry of the many generations of farmers who have lived there since the early part of the eighteenth century. From one of the many ridges which traverse the county it is seen to be thickly settled for a farming district. Often, on a clear day, as many as 50 farms may be counted, all having the large barn, dwelling house, tobacco shed, windmill, and other buildings with which every farm is supplied.

The farms vary in size from a few acres to 200 acres, the average size being about 80 acres. This is considerably less than it was twenty years ago, for during that period there has been a constant decrease in the size of the farms. These farms, in addition to other improvements, always have large barns. They are usually patterned after the Swiss barns, those most complete having a granary on the upper floor, wagon sheds, corncribs, sheds for horse power, thrashing floors, hay mows and lofts, as well as stables and feeding passages in the basement. Under the driveway there is also a cellar, and frequently a tobacco shed is attached. They are substantial structures, the lower parts being built of limestone and brick, with the upper stories generally built of wood and painted red. A good barn of this kind costs in the neighborhood of $4,000, and many are seen which cost as much as $6,000.

The dwellings are well built, comfortable houses of brick or limestone, although they are not quite so pretentious as the barns described. Two thousand five hundred dollars probably represents the average cost of the dwellings, while a good tobacco barn will increase the cost of improvements about another thousand. On the larger farms a tenant house is usually found, which still further increases the amount

of money necessary to equip a good farm. These amounts, added to the cost of substantial fences, smaller buildings, and sheds, make the total cost of improveme· ts a large amount. Still these improvements are always found on the Lancaster County farm of 80 or 100 acres. A characteristic group of farm buildings is shown in Pl. I.

Even without improvements the price of farm land is high in the county, and it is seldom that a well-improved farm in the central portion sells for less than $125 per acre, the price often being from $200 to $300, or even higher within a few miles of Lancaster.

The principal crops grown at the present time are grass, wheat, corn, oats, rye, and tobacco, as well as potatoes, small fruits, and truck for the local markets. All of the crops, with the exception of tobacco, are consumed or manufactured within the county. Instead of hay and grain being shipped out of the county, large quantities of feed are each year brought in and used for fattening cattle. Little or no commercial fertilizers are sold in the county, but special effort is constantly made to increase the productiveness of the land by liberal applications of well-rotted stable manure. As a result, the soils, it is stated, produce far more than they would even a few years ago.

In addition to the crops already mentioned, large quantities of fruit are grown. While there are no large orchards, nor is any special effort made to develop the fruit industry, still every farm is supplied with a few trees, including apples, peaches, pears, cherries, and occasionally apricots, and in the aggregate thousands of bushels of such fruits are annually grown in Lancaster County in addition to grapes and various small fruits.

The tobacco crop is counted on as the main money crop, and many farmers pay the expenses of the farm with the other crops, while the money derived from the sale of tobacco is clear profit. It certainly brings a great deal of money into the county and furnishes employment to a large number of people.

The central portion of Lancaster County is well supplied with railroads, which afford ample means of transportation to Philadelphia and Baltimore markets. In addition to the splendid railroad transportation facilities, many electric car lines have been constructed within the past few years between the principal towns, and others are contemplated. Good limestone pikes lead out in every direction from Lancaster, and these are connected at frequent intervals by fair dirt roads. The toll system is relied upon to keep the pikes in repair. The toll for a one-horse buggy is 2 cents per mile; for a two-horse team, double this amount.

SOILS.

In the 270 square miles of Lancaster County which were surveyed, 11 different classes of soils were recognized and their boundaries outlined on accurate, large-scale maps. Topographic maps were not

available for this work, but the maps used were those prepared for the county commissioners and were found to be exceedingly accurate, so that no difficulty was experienced in locating the soil boundaries.

This section of Pennsylvania is south of the area covered by the ice during glacial times, so that the soils here are, with but two exceptions, the decomposition products of the rocks which are found there. The names adopted for the various soil formations are those of similar soil formations elsewhere or local names which have been selected from the names of creeks or townships.

The different soils have about the following areas:

Areas of the different soils.

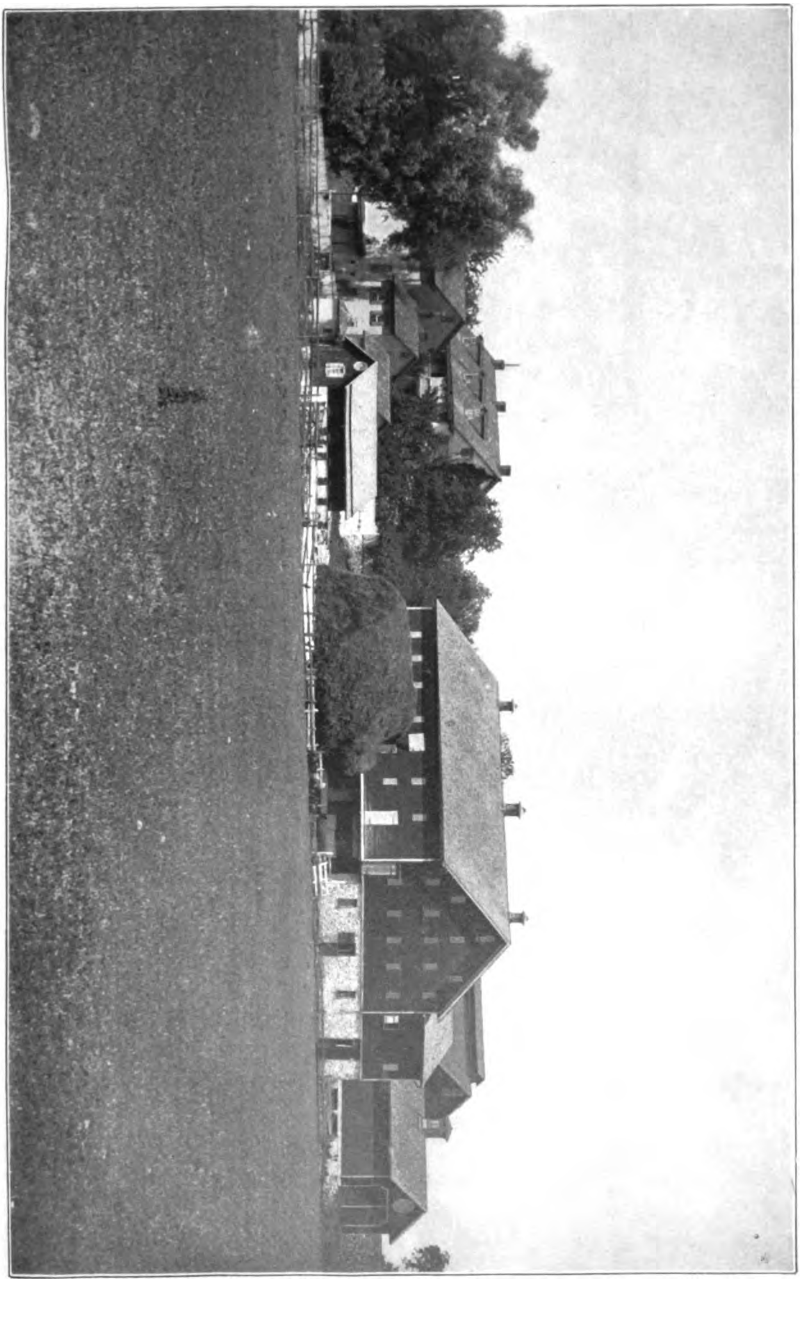
Soils.	Acres.	Per cent.	Soils.	Acres.	Per cent.
Conestoga loam	51,000	29.5	Meadow	6,000	3.4
Hagerstown loam	45,000	26.0	Donegal gravelly loam	4,000	2.3
Hagerstown clay loam	21,000	12.1	Manor stony loam	3,500	2.0
Hagerstown shale loam	15,000	8.6	Hagerstown clay	2,000	1.1
Edgemont stony loam	13,000	7.5	Hempfield stony loam	1,400	.8
Cecil mica loam	10,000	6.1			

HAGERSTOWN LOAM.

Large unbroken areas of this formation occur in the townships of East Hempfield and West Hempfield, Rapho, and East Donegal. The surface is gently rolling, rising from 350 to 400 feet above sea level. There are no marked changes in elevation, but a succession of long, sloping ridges and broad, rounded hills.

The soils of this formation are the residual decay products of massive beds of blue limestone, which were deposited during late Cambrian and early Silurian times. The soils are merely the insoluble portion of the rock which have remained after the lime has been removed in solution, mixed perhaps with the more sandy layers which are occasionally interbedded with the limestone. A feature of the limestone areas here, so common in all limestone countries, is the large number of sinkholes which bear testimony to the manner in which these rocks are honeycombed and dissolved away by percolating rain waters. The Hagerstown loam is well drained and at the same time well watered by scores of small streams. Rain water readily enters these soils, and cases of washing on the slopes, so common in the Southern States, are quite uncommon here.

The soils are yellowish-brown mellow loams, containing a fair proportion of clay. They are from 8 to 12 inches deep and contain a goodly share of organic matter derived from liberal applications of manure, which they receive at least every four or five years. These soils are rich and productive and seldom fail to make good crops of corn, tobacco, wheat, and grass. The subsoil contains less organic matter and a greater proportion of clay, and may be classed as clay



GROUP OF FARM BUILDINGS IN THE LIMESTONE VALLEY OF LANCASTER COUNTY.

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loams. These are generally of a decided yellow, although they may locally be spoken of as red clay. At an average depth of 24 inches the yellow-clay loam grades into a stiff red clay. The exact depth of the clay subsoil varies greatly in different localities, owing largely to the character of the limestone occurring in any particular place. Occasionally the harder beds of limestone may protrude from the ground, but more often they are buried from 3 to 20 feet below the surface. While there may be some trace of cherty limestone or sandstone fragments found on the surface, still there is never a sufficient quantity of large bowlders to seriously interfere with cultivation. These soils are always spoken of as limestone soils and are classed as rich, fertile soils, which bring good prices when well improved. The local differences in the soils are slight. Frequently the brown loam may be deeper at the foot of a long slope, where it has accumulated, while in other places the yellow-clay loam subsoil may continue to a depth of 3 feet before the stiff red clay is reached.

The following table gives the mechanical analyses of typical samples of soils and subsoils of the Hagerstown loam formation:

Mechanical analyses of Hagerstown loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4952	Mechanicsburg, 2 miles E.	0 to 12 inches...	4.63	2.02	3.28	3.25	6.50	11.92	54.28	14.17
4953	Subsoil of 4952...........	12 to 36 inches..	3.19	1.29	1.75	1.84	4.13	10.58	49.57	27.66

The heavy timber growth, described as characteristic of the limestone valleys when the country was first explored, was found on these soils. But little now remains of the once mighty forest. Occasionally a few acres of woodland may be found or some scattered trees in the fields, but they are all that is left of the thick growth of hickory, walnut, and mammoth oaks. The original timber was cut many years ago, and even the small wood lots are rapidly disappearing.

The Hagerstown loam ranks high as fine corn, tobacco, wheat, and grass land. It is best suited to corn and tobacco, although all of the crops mentioned are grown with success. In 1900 the wheat crop was said to have averaged from 20 to 35 bushels per acre, and in a good year from 75 to 80 bushels of corn per acre can be raised. Oats succeed well and make large yields, but they are not grown as extensively as they formerly were. This soil produces a fine filler leaf tobacco, but attempts at growing a wrapper leaf have failed. The leaf is

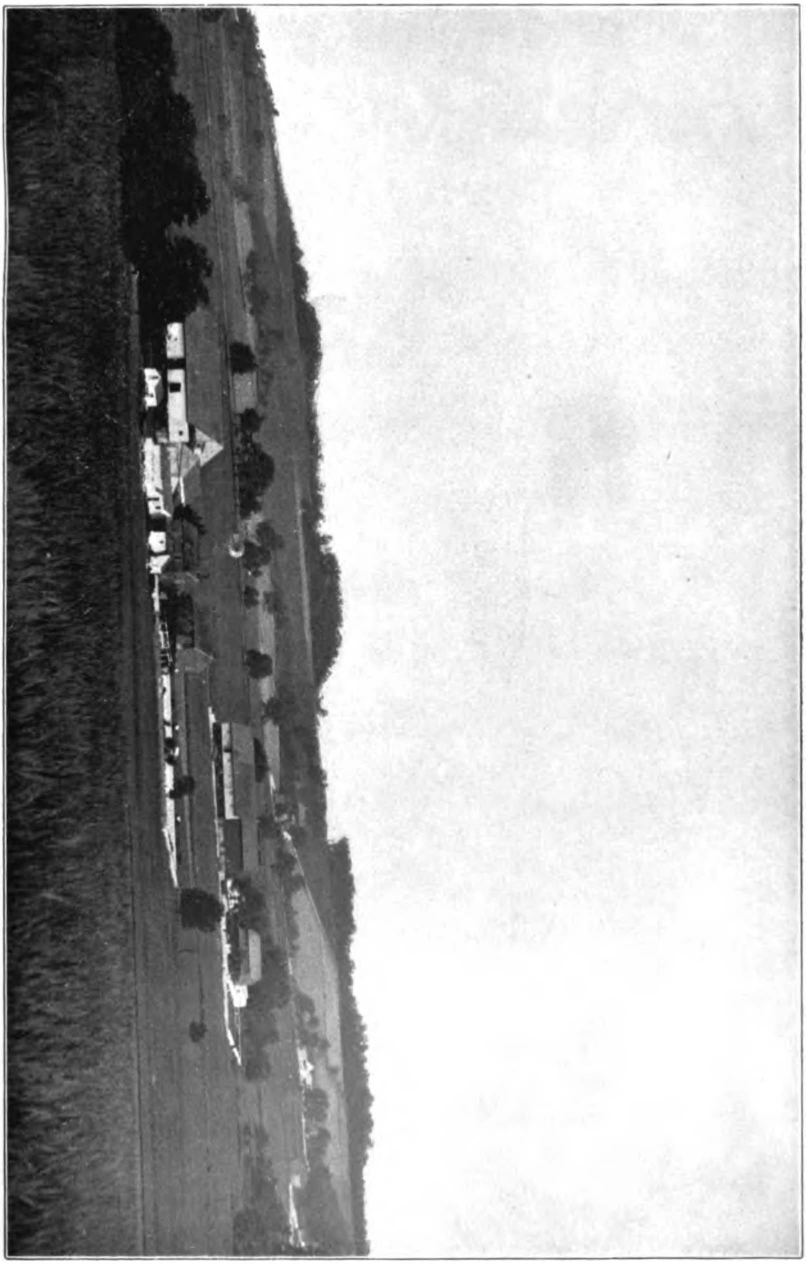
large and thick, has a dark color, and thickens considerably in the sweat. In good years, by proper manuring, from 1,500 to 2,200 pounds of tobacco can be raised on an acre. Tobacco is seldom planted on the same field year after year, but has a place in the regular rotation. Generally it follows the grass crop or is planted on corn ground.

Most of the common fruits succeed well, with the exception of peaches. Many of the fine farms of the country are situated on this formation, and they are all carefully managed by a prosperous class of farmers.

HAGERSTOWN CLAY LOAM.

The Hagerstown clay loam occupies less than one-half the area of the formation just described, the greater part being found in the townships of East Lampeter, Upper Leacock, Manheim, and Warwick. The character of the surface of this formation is quite similar to that of the Lancaster loam—broad, rolling valleys, with gently sloping ridges and low, rounded hills. Along the creeks there are steep hills, through which ledges of limestone protrude, but these form the only contrast to the broad, rolling stretches of country. These soils are likewise derived from the decomposition of thickly-bedded limestone containing occasional thin layers of sandstone. The remarks made concerning the drainage conditions of the Hagerstown loam apply with equal force here.

The Hagerstown clay loam is much heavier than the Hagerstown loam, containing a greater percentage of clay. The soil usually consists of about 10 or 12 inches of a dull reddish-brown clay loam underlaid by stiff clay loam of the same color. At 24 inches a stiff red clay similar to that under the Hagerstown loam is found, and this continues to a depth of several feet. There is a trace of broken, angular quartz fragments on the surface, with occasional pieces of sandstone. The amount of quartz or other rock on the surface rarely exceeds 25 per cent, and is generally less than 10 per cent. These soils are locally called red-clay limestone soils, and were originally covered with a heavy timber growth which has long since been removed. The entire extent of this formation is carefully farmed. Wheat succeeds exceptionally well, and these lands may be considered the best wheat lands of the entire county. From 20 to 40 bushels per acre can be grown. Good crops of grass can also be grown on these soils, and from 1½ to 2 tons of hay per acre may be said to be a fair crop. The practice is to sow timothy and clover seed mixed, but the clover rarely lasts more than one year. Corn and oats do well on these soils, but it is not a typical soil for corn, being stiffer, firmer, and not so mellow as the lighter loams of the formation just described. The usual rotation practiced on these soils is to follow corn with oats, potatoes, or tobacco, then wheat, after which the field is seeded to grass. The grass is allowed to remain two years. This



HAGERSTOWN LOAM VALLEY WITH EDGEMONT STONY LOAM ON THE RIDGE IN THE BACKGROUND.

rotation is varied somewhat according to the number of fields in the farm.

Lime is generally applied during the rotation, or once in every four or five years. Some commercial fertilizers have been applied to these soils, mainly phosphates, but these are said to burn out the soil in a few years, so that their use is not generally recommended. Most of the farms in this formation have a small field of tobacco each year, but the soil is not ideal for tobacco. Yields as large as from the Hagerstown loam are reported for these soils, but they are recognized as being too stiff and clayey for the best results with tobacco. Seed leaf is mostly grown on these soils. This is essentially a filler tobacco, although there is a small percentage of each crop used for wrapper and binder purposes. Attempts at growing Havana seed have generally proved unsuccessful. Farms on the areas of this formation are considered equally as valuable as those on the Hagerstown loam, and, for a farmer who does not wish to grow tobacco, they are worth perhaps more, because, being stronger, they can more successfully stand hard farming.

Mechanical analyses of representative samples of this formation are given in the following table:

Mechanical analyses of Hagerstown clay loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4962	Binkley	0 to 10 inches	5.50	1.01	2.63	2.51	6.40	9.98	58.64	13.64
4966	Landis Valley	0 to 9 inches	5.67	1.81	1.72	1.15	2.41	5.95	65.60	16.06
4967	Subsoil of 4966	9 to 38 inches	6.04	2.84	1.96	2.50	4.98	8.98	47.79	24.44
4963	Subsoil of 4962	10 to 36 inches	4.10	2.16	2.38	2.26	5.17	10.22	46.77	27.14
4961	Witmer, one-third mile NW.	Red-clay loam, 10 to 30 inches.	4.30	2.06	1.75	1.08	1.91	8.48	53.24	27.55

HAGERSTOWN CLAY.

In the area surveyed this formation does not cover more than 2 square miles. The largest areas occur in Manheim township, a few miles northwest of Lancaster. This formation forms part of the broad valley, and is likewise derived from thick beds of comparatively pure limestone of Cambro-Silurian age.

Although this formation is like the Hagerstown loam as regards occurrence and origin, yet the general appearance and texture are very different. These soils may be said to be the Hagerstown loam from which the top covering of loam has been removed, exposing

the clay subsoil, and yet these soils do not occupy positions where erosion is more pronounced than in the case of the first two formations described. However their clayey nature may be accounted for, they are stiff, heavy clay soils, with no trace of the covering of lighter loam. The soil to a depth of 12 inches is a heavy red loam, stiff and tenaceous, overlying a heavy red clay. These soils are generally comparatively free from quartz and sandstone fragments, but, on account of the large amount of clay they contain, are difficult to cultivate. They produce fair crops of corn and tobacco and good crops of wheat and grass. They are well adapted to wheat and grass, but they are too stiff to be generally sought after for general farming. In a dry season they bake and form great clods not easily broken, while in a wet year they dry slowly. Tobacco does not succeed at all well on these soils, as they are too stiff and intractable, and a poor growth is the result. The areas of these soils are so small that it is hard to form an adequate estimate of the value of these lands.

The mechanical analyses of a few samples of the Hagerstown clay soils and subsoils are given in the following table:

Mechanical analyses of Hagerstown clay.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4968	Lititz, one-half mile NE.	0 to 10 inches	6.91	1.10	1.14	0.74	2.93	12.98	61.41	13.94
4970	Petersburg, 1 mile E	0 to 12 inches	4.48	1.68	2.31	1.70	4.73	10.61	56.02	18.48
4969	Subsoil of 4968	10 to 30 inches	5.45	.14	1.02	.84	2.66	8.56	47.77	33.47
4971	Subsoil of 4970	12 to 30 inches	5.07	1.93	1.26	.70	1.98	6.25	38.36	44.63

MEADOW.

Meadows occur as narrow strips along the greater part of the small streams found in the entire area. They seldom exceed one-fourth of a mile in width, but they are such a persistent feature of the small streams that their boundaries were outlined on the map, even at the risk of being exaggerated in a few cases. These are natural meadows, and many of them in the early days were enlarged by damming the small streams, and were used to supply the entire hay crop. At present they are rather insignificant from an agricultural standpoint, although the name "meadow" still clings to them. They occur, typically developed, in the limestone valleys, but are found even in the more hilly portions of the county. They are derived partly from materials carried several miles by the streams and partly from the washings from the neighboring hillsides. Generally there is a large

amount of organic matter contained in these soils, so that to a depth of 12 inches the soil consists of black, heavy loam, grading into a heavy sandy loam resembling muck, or, as in some localities, into a wet, blue clay. The meadows are low, wet, poorly drained, and in their present state not generally cultivated, although some portions which are better drained produce fair crops of timothy hay and corn. Wheat makes a heavy growth of straw, but the heads seldom fill well. Clover does not succeed on these meadow lands. Generally, the meadows are left to furnish pasture for cattle and horses, and for this they are admirably adapted. While the strips of meadow land are narrow, no large areas being found, still the combined areas of the meadows amount to several square miles.

CONESTOGA LOAM.

This formation occupies the largest area in the central portion of the county. It comprises the greater part of East and West Lampeter, Lancaster, and Manor townships, besides the northern part of Pequea and Conestoga, as well as the northern part of East Hempfield. It extends in an unbroken area from near the Susquehanna River, in Manor Township, directly east to Pequea Creek. This area occurs as a broad limestone valley, but it is distinctly different from the limestone valley which is formed by the combined areas of the three formations described above. The hills and ridges which are found in this area are distinctly higher and steeper than in the region to the north of Lancaster. The largest creeks of the county are found in this formation, namely: The Conestoga and Little Conestoga creeks, Mill Creek, and, on the southern border, Pequea Creek. As these creeks traverse the area of the Conestoga loam, they are all characterized by long, winding courses. This is noticeably the case along the southern border of Lancaster city, where the Conestoga makes a series of long, sweeping curves, which form a pleasant feature of the landscape about Lancaster. Frequently these curves are over a mile in length, with narrow, rocky hills between them. Along all of the streams in this area the banks are rough and steep, with projecting ledges of limestone. A good illustration of the more rolling character of this formation, as compared with the other limestone areas, is seen in the fact that the main line of the Pennsylvania Railroad follows along the northern border of the formation rather than going directly through it, which the more direct course would suggest.

The soils of the Conestoga loam are also derived from the residual decay of limestones, but they are not massive limestones, as those found north of the city of Lancaster. On the contrary, the beds of limestone are much folded and metamorphosed, and beds of schistose limestone and veins of calcite of considerable size are frequently seen. The thicker beds of limestone are much rougher in appearance

than are the massive limestones found north of Lancaster. They are locally called sandy limestones, but on close examination they are found to contain no trace of siliceous materials. The soils derived from the weathering of these limestones are seldom as deep as the Hagerstown formations. This is probably due to the character of the rocks from which they are derived. Sink holes, which are common in the limestone valleys north of Lancaster, are not found here. Not only are the larger streams abundant in this formation, but there are a great number of small streams, showing that the greater part of the rainfall runs off in superficial streams rather than in underground channels.

The soil to a depth of 10 inches closely resembles the soil of Hagerstown loam. It is a yellowish-brown loam, mellow, easy to cultivate, and generally contains less quartz fragments and other stones than does the Hagerstown loam, clay loam, or clay. Often there is a trace of broken bits of thin, schist-like rock, ranging in diameter from one-half inch to 2 inches. In many localities the soils have a greasy look, are much lighter in color, and when crumbled between the fingers have a distinctly greasy or soapy feel. This is a property seldom noticed in soils, no matter what their origin may be. It is probably due to the dissemination of exceedingly fine particles of mica (sericite) through the soil. The subsoil, from 10 to 30 inches, consists of a light clay loam of a yellowish color, always possessing the characteristic greasy feel of these soils. At an average depth of 30 inches the subsoils grade into a dark-colored mass of greasy, decomposed schist having a cool, moist feel. Such soils are always well drained unless in low positions, and are therefore warm and dry. They are quite early in the spring on this account, but a long dry season is apt to affect crops late in maturing. They are often spoken of as sandy limestone soils, well adapted to corn and tobacco and other crops which require a light, loamy soil. They are not as strong and productive as the soils which are underlaid by stiff clay subsoils. They make good general farm lands, however, and are as eagerly sought after as the best soils of the county. Twenty-two bushels of wheat per acre is considered a fair average, although even 40 bushels are grown in good years, while from 60 to 80 bushels of corn can be raised on an acre if the season be favorable. Tobacco does well on these soils. It can be planted earlier than on the other limestone soils of the county. A large part of the Havana seed tobacco for cigar wrappers is grown here. The trouble with fleas and worms is not so great and the soils are better adapted to the growth of a thin, elastic leaf suitable for wrapper and binder purposes. From 1,400 to 1,600 pounds of Havana seed and 1,600 pounds of seed leaf are considered good average yields on an acre of land. When the crops of Havana seed tobacco are harvested in good condition they bring much better prices as wrappers than that paid for the average Pennsylvania seed, but

with the diminished yield and greater risks to be borne it is doubtful if growing tobacco on these soils for wrapper purposes is very profitable.

In the following table the texture of typical soils and subsoils of this formation is given:

Mechanical analyses of Conestoga loam.

No	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4976	Soudersberg, one-half mile SE.	Dark loam, 0 to 10 inches.	5.40	0.60	1.44	1.16	7.04	19.96	57.37	7.56
4972	Bausman, 1¼ miles SW.	0 to 10 inches	5.55	3.77	2.82	1.87	9.34	22.21	41.86	12.55
4977	Subsoil of 4976	Light clay loam, 10 to 30 inches.	3.06	Tr.	1.52	.85	5.96	23.08	54.64	10.87
4973	Subsoil of 4972.......	10 to 30 inches	2.84	1.96	3.66	2.76	10.94	27.91	34.30	14.54

EDGEMONT STONY LOAM.

The greater part of the area of Edgemont stony loam is found in the townships of West Hempfield and East Hempfield. There are also small areas in Manor, Manheim, and Upper Leacock townships. These areas are all considerably above the general valley level. The greatest elevation is probably above Columbia, where the Susquehanna has notched the sandstone ridge, forming steep, rocky bluffs on both sides of the river. The elevation along this ridge is in the neighborhood of 200 feet above the valley. This ridge continues unbroken to Rohrerstown, where it terminates in a large, rounded hill. About 4 miles north of Lancaster it is found again occurring in short ridges and bold, rounded knobs. All of these ridges and chains of steep knobs extend in an easterly and westerly direction.

These soils are derived from the decay of a fine-grained, siliceous sandstone or quartzite of Cambrian age. The rock is composed of quartz particles firmly cemented together and well calculated to resist the wearing-down influences of atmospheric decay. For this reason the areas of this rock stand above the valley level. Rocks which decompose as slowly as these are seldom covered with a thick layer of soil. So soon as the weathering influences set free the fine particles of sandstone they are carried away by the rains, so that a considerable thickness of soil is not allowed to accumulate. This is especially noticeable on the steeper slopes where the soil covering consists of only a loose mass of sandstone fragments mingled with a slight amount of sand and decomposed organic matter. On some of the broad, flat-topped hills of this formation, where the influence of washing is not so

marked, a thicker covering of sandy soil is found. The soil rarely exceeds 20 inches in depth and generally is much shallower. Little difference is seen between soil and subsoil. The average soil section in this formation is from 6 to 8 inches of a brown, sandy loam, more or less stony, which grades into a loose mass of sandstones and slates. The surface soil is thickly strewn with angular pieces of flat, flaggy sandstone varying in diameter from 1 to 10 inches. The amount of stones on the surface varies from 30 to 60 per cent. The subsoil, when the soil covering is sufficiently deep to have a subsoil, consists of yellow, sandy loam filled with sandstone fragments. As would be expected, these soils are not strong nor productive, but crops grown upon them possess a quality far superior to that of the more fertile limestone soils. Fruit grown on these soils has a fine flavor, and in some localities, as at Fruitville, raising berries and small fruits has become quite an industry.

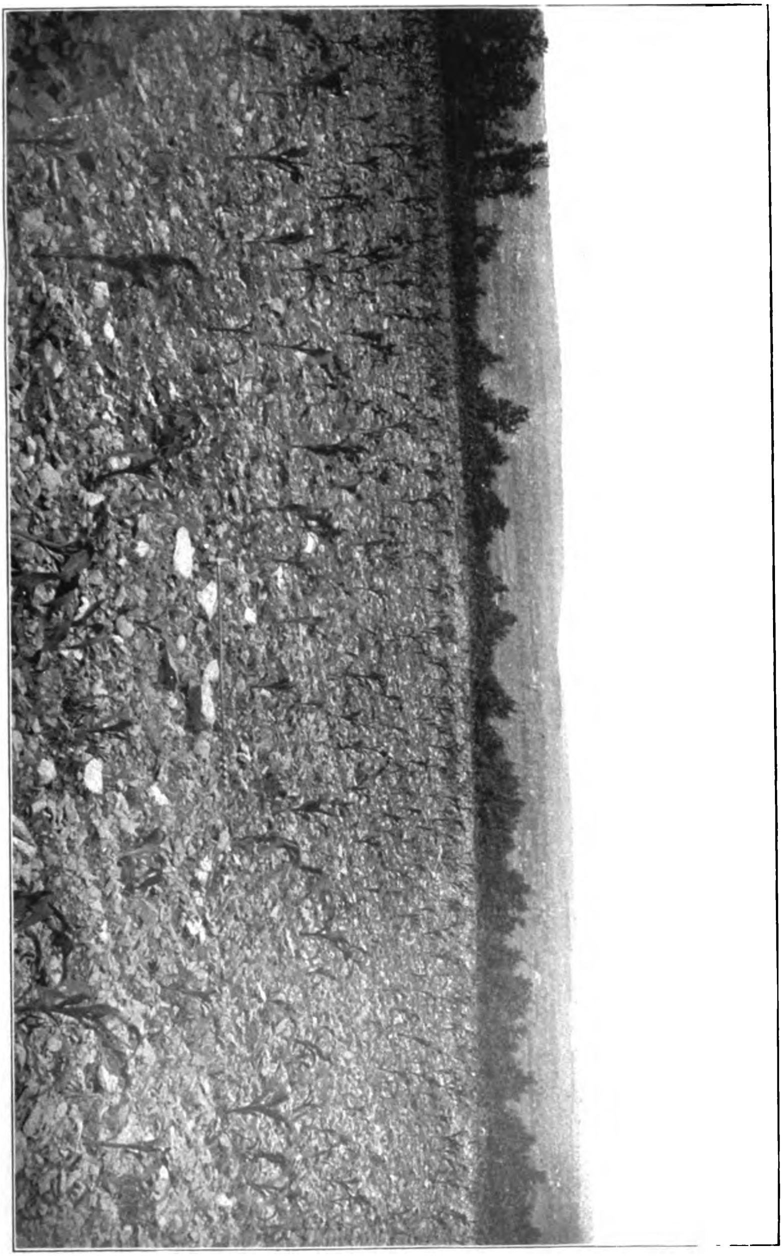
Many successful peach orchards are also seen on the stony lands of this formation. It is upon stony hillsides of this same soil formation that the mountain peach industry has been so successfully developed in Maryland, and, judging from the success attained in small ventures in raising peaches and small fruits in Lancaster County, there seems no reason why the fruit industry should not reach proportional dimensions. The greater part of these ridges is covered with a forest growth of chestnut, locust, and several varieties of oak. On the cleared areas corn, oats, rye, and potatoes are mostly grown. The quality of these crops is always good, but the yield is small. Wheat does fairly well on these soils, in that bright, heavy grain is produced, but the yield is small. They are considered good lands for "hill lands," but they are difficult to cultivate, and require a considerable outlay to make them productive. They are locally known as gravel soils.

In the table following the texture of a few typical samples are compared. They are much lighter than the Hagerstown loam.

Mechanical analyses of Edgemont stony loam.

[Fine earth.]

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4981	Columbia, one-half mile W.	0 to 10 inches	3.78	2.79	7.03	11.02	25.20	27.52	19.16	2.49
4980	Neffsville, 1 mile SE.	0 to 10 inches	14.76	6.80	2.84	3.93	7.56	23.06	38.98	2.61
4979	Mechanicsburg, 1 mile W.	Brown, stony loam, 0 to 12 inches.	3.11	7.92	2.78	2.20	5.28	31.42	40.60	5.72
4982	Subsoil of 4981	10 to 28 inches.	2.28	6.74	8.24	5.20	20.52	24.53	20.79	11.71



CHARACTER OF THE SOIL OF THE EDGEMONT STONY LOAM FORMATION.

Tobacco has not been grown on these gravel soils to any great extent, but it has long been recognized that they produce a fine quality of tobacco, which approaches more nearly to the style of tobacco now in demand for a cigar wrapper than does the tobacco grown on other soils in this area. It is light in color, thin and silky, and with proper care and treatment would probably make a good wrapper leaf. At present, however, it brings but little more in price, while the yield is considerably less than on the limestone soils, so that these soils are not considered good tobacco soils. They will seldom produce more than 1,200 pounds per acre, and will produce this amount only by heavy manuring. South of Neffsville there is a piece of land so stony that the soil appears to be nothing but a loose mass of stones, yet fine crops of tobacco have been raised on this field for twenty-five years in succession. This certainly shows that there are possibilities in these soils which have not been fully realized.

Few if any large farms are situated on this formation, and the land commands a much lower price than in the formations just described.

HAGERSTOWN SHALE LOAM.

The area of the Hagerstown shale loam is slightly larger than that of the last formation described. It covers two areas of considerable size. One begins just north of Mount Joy, in Rapho Township, and continues unbroken in an easterly course across Penn and Warwick townships. The second large area occurs just north of Lititz, surrounding the village of Brunnerville. There are also small areas of this formation situated in East Hempfield Township. The surface features of these areas resemble somewhat those of the Edgemont stony loam just described. (Pl. II.) They are high, rounded ridges rising to a considerable elevation (100 feet or more) above the general valley level. These hills and ridges are symmetrically curved and rounded, and form a more pleasing feature of the landscape than do the bold, steep hills of the formation just described. The soils are derived from the disintegration of fine-grained shales of Mesozoic age. They form a part of the series of Triassic shales and sandstones which traverses so many of the Eastern States from New England far into the Southern States.

These rocks were deposited as fine-grained sediments in comparatively shallow seas. Since they were laid down they have undergone some changes, and appear as thin beds of shales which resist erosion so much better than the limestone that they form ridges and hills. The soils derived from these shales are fine yellowish loams filled with bits of broken shale. In places the soil is merely a mass of loose shale fragments, shallow, easily drained, and suffering greatly from drought in dry seasons. They seldom exceed 18 inches in depth, and generally they are not over 12 inches deep. On the surface the char-

acteristic shale particles are scattered, the particles being rarely more than an inch in thickness although they may be many inches in length. They constitute from 20 to even 60 per cent of the top 8 inches of soil. Such soils wash badly, and on the steeper hill slopes great furrows or gullies may be noticed which, unless soon checked, widen perceptibly from year to year. These soils are also called "gravel lands," and in their natural condition ranked very low as farm lands. Thirty or forty years ago they were hardly cultivated at all, but were allowed to grow up in mullein and other weeds. It was not considered that they would produce much of anything, but were used as short pastures which dried up at the approach of hot weather. Since then, however, by means of frequent applications of manure and by careful cultivation they have been made fairly productive. They are said to produce about 25 per cent less than the Hagerstown loam. Fruit succeeds fairly well on such soils, but there has been no special effort to develop the industry. The remarks made about the crop conditions of the Edgemont stony loam apply with equal force here. The yields are light but of good quality. Corn, oats, rye, clover, and wheat are grown on the cleared lands, but many large forested areas remain. Chestnut trees abound largely in the forests. Tobacco grown on these soils is thin, light-colored, fine-textured, better adapted for a wrapper than for a filler leaf, as it is flimsy and has not sufficient body for a filler leaf. If a special effort were made to produce a fine, thin wrapper leaf it would probably prove profitable, but at present it is only recognized that these soils produce a comparatively light yield, which will not bring an advanced price, and consequently they are regarded as poor tobacco soils. Uncleared forest land in this formation does not bring a high price, for the cost of clearing is considerable, as well as are the subsequent expense and labor necessary to make the soil productive.

The following table gives the mechanical analyses of typical samples of the Hagerstown shale-loam soils:

Mechanical analyses of Hagerstown shale loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4983	Brunnerville, one-half mile S.	0 to 10 inches	7.68	10.94	5.16	3.70	3.64	8.22	47.90	12.35
4985	Kissel Hill	Yellow shaly loam, 0 to 10 inches.	6.70	16.25	7.72	2.56	5.11	4.87	32.06	24.92

CECIL MICA LOAM.

This formation occupies the greater part of Conestoga and the southern part of Pequea townships. The formation also occupies a small portion in the southwestern part of West Lampeter Township. The surface is characterized by high rolling country along the Pequea and Conestoga creeks and Susquehanna River. Long ridges and steep-sided valleys form a feature of the topography rather than rounded hills. Along the Susquehanna the banks are high, bold bluffs, heavily timbered, rising considerably over 100 feet above the river bed. The rocks from which these soils were derived belong to the older system of rocks, whose origin have to the present been an unsolved problem. They form a part of the complex system of rocks which constitute the Piedmont plateau of the Atlantic Coast States.

The rocks consist of a fine grayish mica schist, which weathers into heavy sandy loams of a yellowish color, completely filled with particles of fine muscovite mica or isinglass, as it is commonly called. The subsoil has a lighter yellow color, and contains a greater percentage of small mica flakes. At an average depth of 30 inches the subsoil grades into partially decomposed schist and loose stones. These soils are not strong enough to stand hard farming, but with careful management they can be made to produce fair crops of corn, oats, wheat, and grass. When the season is just right they compare favorably with the better class of soils found in the county. Care must always be taken on the steep slopes to prevent them from being ruined for cultivation by gullies. Generally, the surface of this formation is free from stones or bowlders, except on the narrow crests of the steepest ridges, where from 10 to 40 per cent of stones is noticed. Although the rocks from which these soils are derived do not weather rapidly, still they are soft, and along the roadways they cut deeply, and most of the roads in the area of Cecil mica loam are several feet below the surface of the fields. This is a characteristic feature of the roads in similar soil areas of the Piedmont Plateau whether these rocks occur in Pennsylvania or in one of the States hundreds of miles farther south.

Many peach orchards are seen on the steep hill slopes of this formation, and, judging from the present success, there seems no reason why the cultivation of peaches should not be developed with a fair degree of profit to the grower. Some tobacco is raised, but the crop is not so extensively cultivated as on the areas farther north in the county. The tobacco is said to be of fine grade, but as the yield is rather light the raising of tobacco has not received much attention. The newly cleared fields produce a fair wrapper tobacco, but after the lands have become somewhat worn they grow a leaf better adapted to filler purposes.

The mechanical analyses of typical samples are given in the following table:

Mechanical analyses of Cecil mica loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4988	Baumgardon, 1 mile NE.	0 to 10 inches	3.97	7.47	4.20	2.19	13.94	29.72	32.00	7.53
4986	Conestoga Center, 1 mile E.	0 to 10 inches	4.10	4.53	2.87	3.20	11.48	30.73	29.79	13.06
4989	Subsoil of 4988	10 to 30 inches	3.69	5.68	4.51	2.65	15.05	25.90	32.81	9.85
4987	Subsoil of 4986	Yellow micaceous loam, 10 to 40 inches.	3.15	10.65	6.79	3.24	17.53	18.70	25.28	14.91

MANOR STONY LOAM.

An area of about 5 square miles occurs in the southwestern part of Manor Township. On its eastern border it comes in contact with the

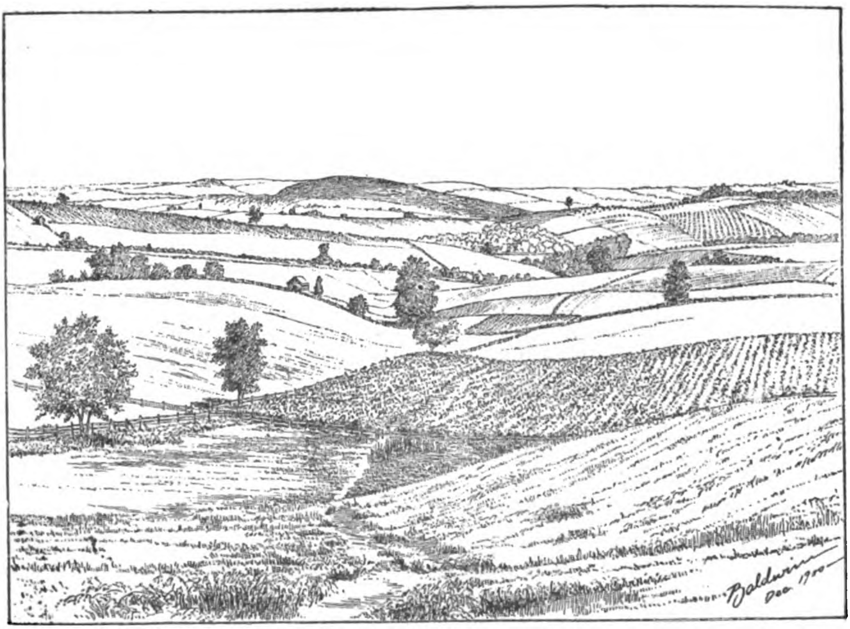
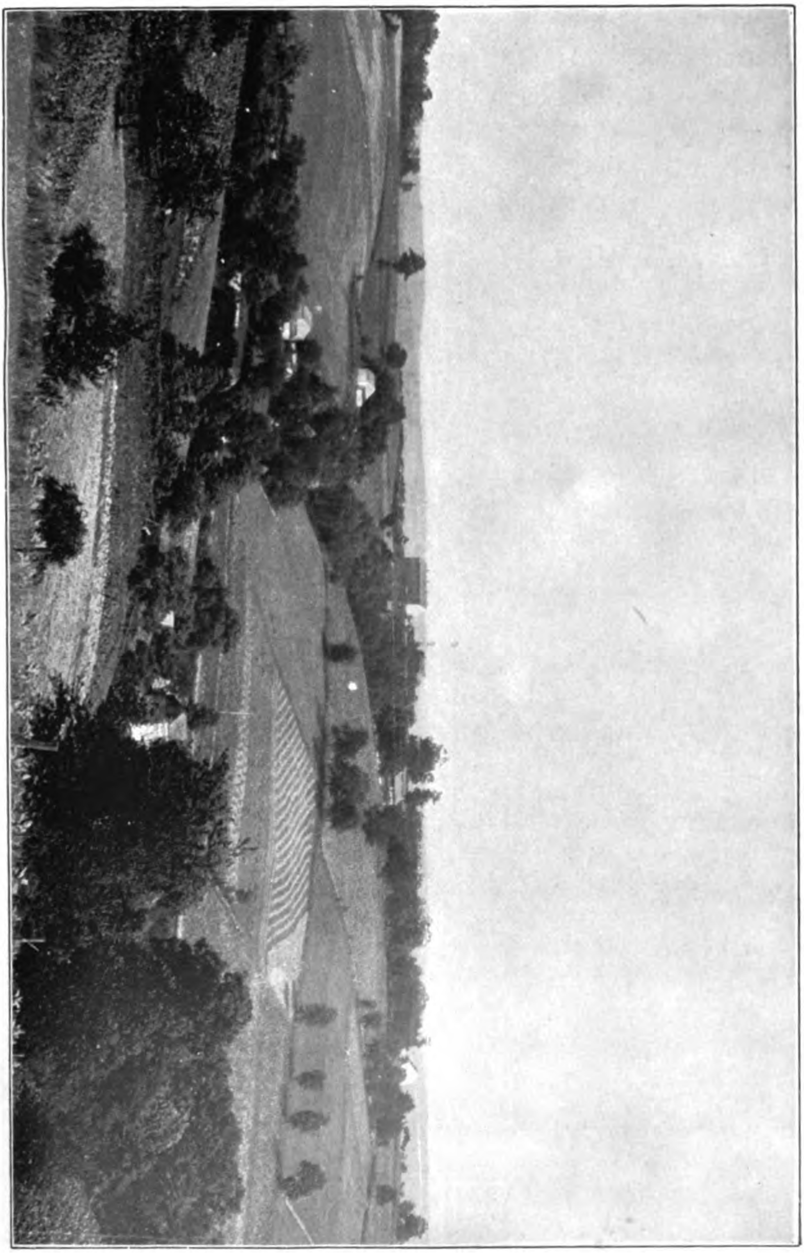


FIG. 2.—Rolling character of country in Manor stony loam in the southern part of the area.

large area of Conestoga loam; along the southern border is Conestoga Creek, while along the entire western boundary is the broad Susquehanna River. The topography of this formation is quite similar to that of the Cecil mica loam, except that the hills along Conestoga



CHARACTER OF THE COUNTRY IN CECIL MICA LOAM AREA.

Creek and the Susquehanna are slightly higher. Along the Susquehanna the hills rise abruptly to an elevation of 200 feet above the river bed. (Fig. 2.)

The soils are derived from a fine schistose rock in which there has been a great development of chlorite—a green, iron-bearing mineral. These rocks, like the schists from which the Cecil mica loam is derived, belong to the series of greatly metamorphosed rocks which constitute to such a great extent the area of the Piedmont Plateau. The chlorite schists of this formation weather into soils which resemble somewha the Conestoga loam and the Cecil mica loam. In texture they are midway between them. The surface soil to a depth of 8 inches is a yellowish red loam possessing to a marked degree the greasy feel so characteristic of Conestoga loam. The subsoil contains considerably more clay and has a more decided reddish color than the surface soil. A constant feature of this formation is the amount of stones scattered over the surface and mingled with the soil and subsoil. These stones are the weathered beds of schist, and are from 3 to 10 inches in length, of a reddish color, and club-shaped. The amount of stones on the surface varies from 20 to 60 per cent, the greatest number being on the highest hills and steepest slopes. At an average depth of 30 inches the subsoils grade into a loose mass of broken schist fragments. Many successful peach orchards are seen on the hillsides in this formation. Fair crops of corn, wheat, grass, oats, rye, and potatoes are raised, but these soils are not considered as safe as the Conestoga loam, which they somewhat resemble. Tobacco is not extensively grown, but dealers say that they have seen crops of tobacco from this section which compared favorably with the best grown in the county. Lands in this formation do not bring high prices compared with the more fertile valley soils, but there are many prosperous farms in this part of Manor Township, and a fair profit can be realized from cultivating these soils.

The mechanical analyses of a few typical samples are given in the following table:

Mechanical analyses of Manor stony loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4992	Creswell, one-half mile W.	0 to 10 inches.....	7.80	1.74	1.32	1.15	8.63	21.01	48.94	9.86
4990	Pittsburg, 1 mile W..	.....do............	5.34	6.60	2.61	1.70	8.49	16.93	43.37	15.33
4991	Subsoil of 4990........	10 to 30 inches....	4.32	5.10	3.07	1.68	13.06	26.52	28.83	17.69
4993	Subsoil of 4992........	.....do............	5.44	2.50	1.39	1.04	7.65	17.84	43.55	20.12

HEMPFIELD STONY LOAM.

Eight small areas of the Hempfield stony loam are located in the western part of the county surveyed. The largest of these areas does not cover more than one-half square mile, while the combined extent of the several areas does not exceed more than 2 square miles. The occurrence of the areas of this formation is in the limestone valleys, and they merely form slight ridges or rocky knobs, which rise but a short distance above the general level of the valley floor. The soil is derived from the decay of a fine-grained, dark-blue rock, which is very hard and is locally known as ironstone. The rock is doubtless an intrusive diabase of Mesozoic age which has cut across the limestones in this section of the country. The soils derived from this rock always have a deep-red color, quite distinct from the red color of the clays derived from the weathering of limestones. The top soil is a heavy, red sandy loam to a depth of 10 or 12 inches, under which is found a heavy, red clay loam. In texture this soil is quite similar to Hagerstown clay loam. The distinguishing characteristics are the deep-red color and the large amounts of rounded stones. Formerly many of the fields of this formation were strewn with large, well-rounded boulders from 1 to 3 feet in diameter. These have all been removed, but the surface is still thickly strewn with the rounded "ironstones" varying from 2 to 6 inches in diameter. The percentage of stones on the surface varies from 30 to 60 per cent. The areas of this soil formation are so limited in extent that it is difficult to estimate their productiveness. They rank as heavy, strong clay soils, and in large fields, where they occur along with the limestone soils, little or no difference is seen between the crop on the respective soils. The large amount of stones on the surface makes them difficult to cultivate, and for this reason they are not held in high esteem.

DONEGAL GRAVELLY LOAM.

Donegal gravelly loams occur as low, poorly preserved terraces along the Susquehanna River in East Donegal, West Hempfield, and Manor townships. These terraces usually extend back one-half mile from the river bank and gradually merge into the rolling limestone areas. The only place where they are found is where the river cuts across the limestone beds. In all other places the rocks have been too hard and resistant, and steep, bold cliffs occur with no room for the formation of terraces. They rise from 10 to 30 feet above the river level, depending upon the amount of erosion they have undergone subsequent to their deposition. Occasionally there are remnants of two formerly well-defined terraces. Rowenna, Marietta, Columbia, Shultztown, and Washington Borough are all situated on these terraces. The terrace in West Hempfield Township is completely covered by the city of Columbia.

These terraces were doubtless deposited by the Susquehanna River

during the time when the northern part of the county was covered by masses of melting ice at the close of the glacial epoch. They are composed of sand and gravel in constantly changing proportions, depending on the strength of the currents of the stream at the time they were deposited. The small streams flowing across these terraces have considerably altered their surface until they appear as a series of small rounded hills extending along the river for miles.

The soils of these eroded terraces change rapidly in short distances, according to the character of the materials from which they are derived. A field of a few acres may have a gravelly soil composed of sand mixed with well-rounded gravel from 1 to 4 inches in diameter. A few hundred feet distant the soil is a reddish-brown sand, not unlike the soils of the Connecticut River Valley, and so these soils change from a sandy to a gravelly nature so rapidly that it is difficult to ascribe any exact or constant character to this formation. They constitute a class of sandy and gravelly soils, which have no counterpart in the other portions of the county. For general agricultural purposes they have little value, but for growing truck or crops which need a light porous soil they far excel any of the soil formations yet described. Above Marietta they produce fine crops of corn, tomatoes, strawberries, melons, sweet potatoes, peas, beans, etc. For producing a fine, thin leaf, suitable for wrapping and binding cigars, these soils are far ahead of any soils which occur in the county, and good crops from these soils equal in quality the tobacco grown in Connecticut. The larger islands in the Susquehanna also have sandy soils and produce equally fine crops of tobacco. This tobacco commands a good price, and a large amount is grown on these alluvial lands and the larger islands in the river.

The table following gives the mechanical analyses of soils and subsoils of the Donegal gravelly loam formation:

Mechanical ana lyses of Donegal gravelly loam.

[Fine earth.]

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
4996	Washington Borough	0 to 10 inches....	1.96	.00	2.56	27.86	15.16	36.48	11.84	3.27
4994	Washington Borough 1 mile S.	.....do	4.34	......	Tr.	12.13	8.33	45.39	25.23	3.86
4997	Subsoil of 4996........	10 to 30 inches...	1.98	......	2.58	26.18	15.27	35.03	13.35	5.48
4995	Subsoil of 4994........	.....do	2.12	......	Tr.	18.74	11.44	41.00	20.25	6.20
4999	Marietta (north of)..	10 to 24 inches...	2.68	Tr.	2.16	6.02	4.02	21.18	50.24	12.71

ACKNOWLEDGMENTS.

The author wishes to acknowledge his indebtedness to Mr. Frank R. Diffenderfer for information and statistics in regard to the portion of Lancaster County that was surveyed; also to Capt. John R. Bricker, Mr. Ezra Herr, and others for valuable data relating to the district. The county commissioners kindly loaned maps, which were of assistance in beginning the survey. Credit is due prominent tobacco dealers for interest and information about the tobacco industry of the county. Messrs. R. T. Avon Burke and George N. Coffey, of the Division of Soils, each personally assisted in the work of the soil survey.

SOIL SURVEY OF MONTGOMERY COUNTY, OHIO.

By CLARENCE W. DORSEY and GEORGE N. COFFEY.

INTRODUCTION.

Montgomery County is situated in the southwestern corner of Ohio (see fig. 3) and covers an area of 480 square miles, or 307,200 acres. It lies between 39° 36′ and 39° 56′ north latitude and 84° 4′ and 84° 29′ west

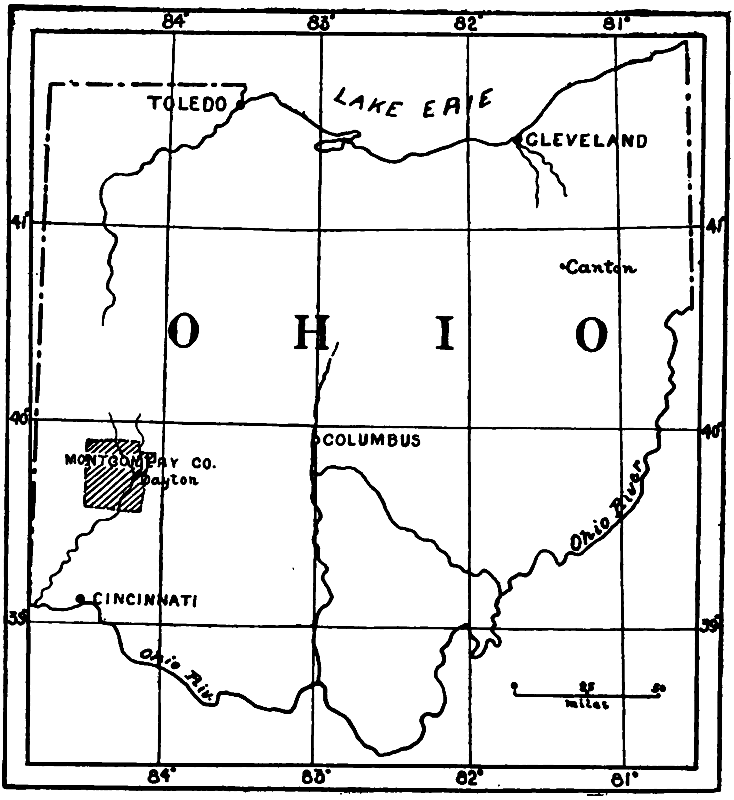


FIG. 3.—Sketch map of Ohio, showing position of Montgomery County and area surveyed.

longitude. The greatest length of the county is 23 miles, while the width in the northern part of the county is about the same. Tobacco is grown in every township in the county and finds a ready market in Dayton, the county seat, one of the flourishing manufacturing cities of Ohio.

PHYSIOGRAPHY.

The surface features partake largely of the general conditions prevailing in the southwestern part of the State, namely: A broad, gently rolling plateau through which the principal streams have carved wide and fertile valleys. The rolling plateau in Montgomery County is traversed by the extensive valleys of the Great Miami, Stillwater, and Mad rivers, as well as by minor valleys along Twin, Bear, and Wolf creeks. The greatest area of these valleys is at the junction of Stillwater and Mad rivers with the Great Miami, where the city of Dayton is located. Here the valley is several miles in width, and consists of a series of well-marked terraces bounded on either side by high, steep hills. The broad terraces are a constant feature of all the river valleys in the county; often as many as five distinct terraces can be observed. Generally, the valleys are inclosed by high hills, but this is not the case north and south of Harshmanville and west of Carrollton. In these two cases the valleys slope imperceptibly into the uplands without any prominent line of demarcation. At Harshmanville the valley floor is 780 feet above sea level, at Miamisburg the river's bed is 266 feet above low water at Cincinnati, or 698 feet above sea level. The Great Miami River falls 100 feet in a distance of 33 miles in traversing the county.

The upland is more or less broken, depending somewhat upon the distance from the larger streams. The upland at one time undoubtedly presented a remarkably even surface, but the small streams have modified this level surface to a considerable extent. Even in the more hilly portions of the county the remains of this once level surface are seen in the perfectly level sky line now attained by the highest hills. In the northern and northwestern part of the county the level character of this old plain is still seen, for the small streams have not as yet carved out deep channels. In Clay, Randolph, and Butler townships the country is very level, and one can see for miles on the straight roads with no distinct change in elevation. The general level of the upland in these townships is about 1,000 feet above sea level and 300 feet above the valley floor at Dayton. This section of the country was originally poorly drained and there were many large swamps, but these have long since been ditched and are now as dry as the more hilly sections of the county.

The southwestern and southeastern parts of the county are hilly and broken, the southwestern corner of German Township being especially hilly. The hills northeast of Germantown are commonly regarded as the highest hills in the county, although they do not rise above the elevation given for the northwestern townships. West of Dayton, where the National Soldiers' Home is located, a rather prominent ridge extends north and south for several miles. In Van Buren and Harrison townships there are prominent gravel hills. The hills bordering the valleys rise from 80 to 150 feet above the valley floors.

The surface of the county slopes gradually to the south, hence all of the drainage is in that direction.

GEOLOGY.

The geology of Montgomery County also partakes largely of the geology of this section of Ohio. The underground geology consists of nearly horizontal beds of upper and lower Silurian shales and limestones. The Upper Silurian is represented by the Niagara and Clinton series. These are found only on the high hilltops of the county, and the total thickness of the two formations rarely exceeds 60 feet. The Niagara consists of limestone and shale. The shale contains a valuable building stone known as the Dayton stone. This consists largely of lime carbonate and is a strong, evenly bedded, compact stone, well suited for building purposes. The Clinton series consists of crinoidal limestones. The Lower Silurian in Montgomery County has been commonly referred to as the Cincinnati group. This formation is the equivalent of the Hudson River shales in the eastern part of the United States, and in this locality is often called "blue limestone." It has a thickness in different parts of the county varying from 150 to 225 feet. The upper layers of this formation are somewhat sandy and serve as a good fire brick or building stone. Fine exposures of these rocks are seen along the small streams where they cut through the steep hills bordering the valleys.

These underground formations rarely outcrop on the surface, for they are generally buried under a thick coating of glacial débris or drift. This drift is composed of a heterogeneous mixture of ground-up rock fragments, containing bowlders, gravel, sand, and clay in varying proportions, deposited over the entire country when a great continental ice sheet covered this section of the United States. The drift on the uplands is called bowlder clay, as it is believed to be actually derived from the grinding up of bowlders. It is the most characteristic of the drift deposits and is now believed to have been formed under extensive ice sheets. The bowlder clay is a stiff clay mixed with angular and rounded gravel, bowlders, and varying amounts of sand. It has not been modified, to any considerable extent, by running water, while the drift found in the valleys shows clearly the assorting agency of swift currents of running water. The drift in the valleys is characterized by a lack of the bowlders, which form so prominent a feature of the uplands. These bowlders have been transported distances varying from a few miles to several hundred miles. They are derived from the bed rock of northwestern Ohio, the Clinton, Niagara, Waterlime, Corniferous, and black slate. Old metamorphosed granites, gneisses, schists, from the shores of Lake Superior and the Canadian highlands, are also represented in the erratic bowlders scattered about over the surface. The deposits of drift materials range from a few feet to over 100 feet in depth. A

general profile of the valley is shown in fig. 4. On many of the hills along the roadways where the deposits of drift have been removed the scratches or grooves made by the ice in passing over the underlying limestones can be distinctly seen. These were made by the hard bowlders which the glacier held imprisoned under the great mass of ice. These scratches always indicate that the ice advanced from the northwest over this part of Ohio.

CLIMATE.

The climate of southwestern Ohio is quite similar to the climate of the central portion of the United States. It is one of considerable extremes, varying from —10° or —15° in cold winters to 100° above zero in hot, dry summers. The extreme annual range of temperature is thus not far from 115°. Although rainfall and temperature records have been kept in Dayton for a number of years, the figures are not so reliable as those given by the regular United States Weather Bureau office at Cincinnati, and the climatological data in the following table are for the latter place. As Cincinnati is not over 35 miles distant from the southern boundary of Montgomery County, there

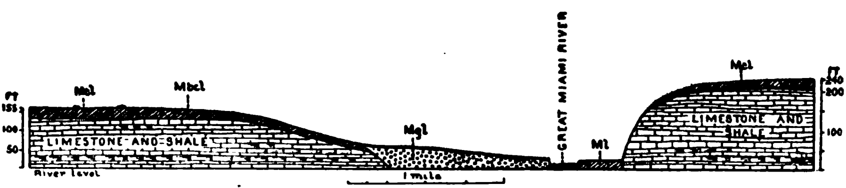


FIG. 4.—Profile across valley of Great Miami River, north of Miamisburg: *Mcl*, Miami clay loam; *Ml*, Miami loam: *Mgl*, Miami gravelly loam; *Mbcl*, Miami black clay loam.

will be but little difference in the normals given and the conditions for Montgomery County.

Climatological data for southwestern Ohio.

Month.	Mean maximum temperature.	Mean minimum temperature.	Mean monthly temperature.	Average monthly rainfall.	Mean relative humidity.
	°F.	*°F.*	*°F.*	*Inches.*	*Per cent.*
April	63	45	55	3.8	61
May	74	57	65	4.0	63
June	81	65	74	4.4	65
July	86	69	77	3.9	65
August	84	67	75	3.8	65
September	78	62	68	3.0	69
Annual	63.8	48.9	56	*a* 22.4	69

a Total for six months.

CONDITIONS OF AGRICULTURE.

At the time of the first expedition to this portion of the valley, in the latter part of the eighteenth century, the country was an unbro-

ken forest with the exception of small open prairies and wet, swampy places, the wet places being covered with long, waving grasses. The rich bottom lands were not so heavily timbered as the uplands, but were covered with a tangled mass of vines and weeds and thick underbrush. The prairie lands were few and of small extent. One of these was said to have been located in the bottom lands where Dayton now stands. The black bottom lands were the first to be settled, while the level uplands, much of which was quite swampy, were regarded as poor land and were little sought after.

The first permanent settlements were made in 1795 and 1796, and as early as 1797 it is mentioned, in the old histories, that crops of corn, hemp, flax, beans, turnips, cabbage, and potatoes were raised. Tobacco is also said to have been grown by these early pioneers, but it was probably in limited quantities if, indeed, it was grown at all. In this same year, 1797, a large quantity of maple sugar was made by evaporating the sap of the sugar maples, these trees growing very plentifully on the uplands. Wild grass and corn fodder were used for cattle and horse feed, as clover and timothy hay were unknown in those days. Montgomery County was formed in May, 1803, and since that time a steady advancement has been made along the lines of successful agriculture.

Although but little more than one hundred years have passed since the early settlers planted their first crops, Montgomery County now ranks high in the production of the staple crops, such as wheat, corn, tobacco, oats, rye, and potatoes. There are few large farms in the county, and even these are rapidly being divided. The average farm contains from 100 to 120 acres, of which about 10 or 12 acres still remain uncleared. In the valleys there is comparatively little woodland, but on the uplands, especially on the more level portions, there are long stretches of native forests. While the farms do not command the prices they did a few years ago, owing to the general depreciation in farming districts, they compare favorably with the more prosperous farming sections of Ohio. The farms of the entire county are assessed at $50 per acre, and this represents slightly more than three-fourths of their actual value. A well-improved farm of 160 acres will bring from $60 to $75 per acre, and the best farms will sell for $100 per acre. The improvements on a good farm are rather extensive and include a comfortable dwelling house, large, roomy barn, capable of housing the live stock, with room for the hay and grain crops. Usually there is a tobacco barn or shed and smaller wagon shed, corn cribs, and minor buildings. In all, these buildings have a value of several thousand dollars. The farms are all well fenced with old-fashioned worm fences, board and wire fences, and, in many places, a farm will be completely fenced with neatly trimmed osage-orange hedge fences. The latter, if well cared for, outlast the other fences, are strong, and at the same time add to the attractiveness of the farm surroundings.

While some portions of the county are naturally more fertile and productive and were on this account eagerly sought after by the early settlers, these differences are not so apparent as they formerly were. The whole county is carefully cultivated and in a prosperous condition. This is the case in the northwestern part of the county, even where there were originally many large, swampy tracts of land. The bottom lands produce fine crops of corn, while the clay uplands are adapted to the raising of wheat, tobacco, and corn. The facilities for shipping are good, for there are three main lines of railroad which cross the county, besides other railroads of less importance. There are also a number of well-equipped electric traction roads which lead from Dayton to the county seats of adjoining counties. Free pikes, maintained at the expense of the county, radiate in every direction from Dayton throughout the county. In addition, good gravel roads laid out on section and half-section lines furnish the farmer ample means of communication with the railroads and towns. Across the creeks and rivers are well-built, substantial bridges, maintained at the expense of the county. The city of Dayton also contributes largely to the expense of the larger bridges and the more important pikes.

The tobacco industry was first developed largely on the rich soils of the broad, fertile river bottoms. At that time little effort was made to grow a fine quality of tobacco. The main object was to produce a large yield, hence the rich soils of the bottoms were in demand and the tobacco was used for shipping purposes and for binders and wrappers of cheap cigars. With the changes that came in the character and quality of the leaf demanded by the dealers, the rich first bottoms were given up to a great extent, and now the rolling uplands furnish the best filler leaf grown in the county. Montgomery County easily leads in the amount of tobacco grown in the Miami Valley, as well as in the quality of the leaf. The crop from the entire valley is sold as Montgomery County tobacco.

The fruit industry in Montgomery County deserves mention. Peaches, apples, pears, cherries, and grapes are grown in abundance. Every farm has an apple orchard of a few acres, besides a number of cherry trees and peach trees. Pear orchards are quite common on the uplands, and the pear industry ranks high in the county. Growing peaches for market is also an important industry, while the annual sale of small fruits and garden products amounts to almost $100,000. It will thus be seen that Montgomery County has made considerable progress in the field of agriculture, and well deserves the high rank it occupies.

SOILS.

The soils of Montgomery County are derived from the weathering and modification of the great sheet of glacial drift which was left upon the country. They depend for their crop values largely upon the

proportion of sand and clay they contain, upon their relation to drainage conditions, and upon the relative amounts of organic matter which is incorporated in them. The soils of the county readily fall into two classes, the river-bottom soils and upland soils. The first class is undoubtedly derived from the glacial drift, but this has been so largely modified by stream action that the soils may be put in a separate class from those derived directly from the weathering of the glacial débris or drift.

The soils have approximately the following areas:

Areas of the different soils.

Soils.	Acres.	Per cent.	Soils.	Acres.	Per cent.
Miami clay loam	240,000	78.9	Miami loam	14,000	4.5
Miami gravelly loam	24,000	7.8	Meadow	7,200	2.3
Miami black clay loam	18,000	5.8	Miami sandy loam	4,000	1.1

MIAMI SANDY LOAM.

The Miami sandy loam, as will be seen on the soil map accompanying this report, occupies the smallest area in Montgomery County. It occurs in strips along the river and stream bottoms. The largest area is found along Bear Creek, but there is also a considerable area below Dayton. The latter is the most important of all from the agricultural standpoint. This formation is derived mainly from river wash, and is subject to change from year to year, depending upon the occurrence of floods in the streams along which they occur. The sand represents the ground-up particles of ice-transported bowlders, which occur on the surface of the uplands, mingled with the thick deposits of drift. The areas of Miami sandy loam lie from 6 to 15 feet above the level of the stream beds, so that they are subject to overflow in times of high water.

The soil consists of a brownish or reddish-brown sandy loam to a depth of 24 inches, under which well-rounded, stratified gravel is generally found. In the different areas where these sandy loams are found the size of the sand grains varies somewhat. Generally, it is a rather coarse grade of sand, principally quartz mixed with small amounts of fine and coarse gravel. The amount of gravel on the surface ranges from 10 to 20 per cent, so that it is in sufficient quantity to be a factor in cultivation. These are sandy soils, and although they occupy low positions in stream bottoms they, on account of their sandy nature, are well drained, warm, and dry during the greater part of the growing season. These soils are always spoken of as first-bottom soils, but they do not contain nearly as much organic matter as the Miami loam, which is also a first bottom along the rivers. Along Bear Creek no attempts have been made to grow crops especially adapted to the sandy nature of these soils, but this is not the case in the area south of Dayton

along the Cincinnati pike. The nearness to the city has been taken advantage of, and large quantities of melons, sweet potatoes, cabbage, and other truck crops are annually grown. In all the other areas of this formation corn is the principal crop, and it produces good yields. Some few tobacco fields were observed, but on such soils in a season so well supplied with frequent showers as the season of 1900 the growth is rank, and much difficulty would be experienced in preventing the rapid growth of weeds. In places these soils closely resemble some of the sandy soils of the Connecticut River Valley, on which such a fine quality of wrapper leaf is grown; but the low position of the Miami sandy loam along the rivers rather offsets the sandy character of the soil, and it is doubtful if any great progress could be made in producing other than a medium-grade wrapper leaf.

The following table gives the mechanical analyses of some characteristic samples of Miami sandy loams, soils, and subsoils:

Mechanical analyses of Miami sandy loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5002	South of Dayton	0 to 10 inches	2.30	2.90	16.85	34.80	16.05	9.58	11.44	5.30
5000	Liberty, 1 mile SW	0 to 12 inches	4.20	2.68	3.60	13.22	31.20	28.90	8.34	7.00
5001	Subsoil of 5000	12 to 36 inches	3.27	1.88	5.05	19.63	31.72	19.70	9.64	9.84

MIAMI LOAM.

Miami loam occupies a position similar to that of the formation just described, that is, broad, flat terraces situated along the principal rivers and streams of the county. The greatest development of this formation is along the Great Miami, but there are also considerable areas along Stillwater and Mad rivers, as well as on Twin and Wolf creeks. The formation occurs as level or gently rolling terraces about 10 or 20 feet above the river bed. Unless protected by extensive systems of levees, they are subject to overflow during high water, which generally occurs during the spring of the year. The water does not remain so long on the bottom lands as formerly. When the country was first settled it was said that these broad bottoms would be flooded for weeks in the spring of the year. The bottoms were heavily timbered then, and the rivers were filled with obstructions, consisting of masses of logs and driftwood, which prevented the rapid lowering of the streams. Now they are subject to an overflow of several feet, which is probably greater than when the valley was first explored. Then the uplands as well as the valleys were thickly for-

ested and the melting of the winter snows was more gradual, and the rivers consequently rose and fell more slowly than at the present time.

As might be expected, these soils are the deposits of the rivers, thoroughly mixed with decayed organic remains of the luxuriant forest and the undergrowth. From the manner of their formation by the river currents one would suppose that these soils would vary greatly in character in different parts of the valley, but such is not the case. These deposits are much the same in character, whether they occur in the northern or southern part of the county. It is the manner of their origin, during the many floods of the rivers, which accumulates a thick deposit of mixed sand and silt and vegetable refuse, and gives them their great productive value. The soil consists of a rich, black, heavy loam, slightly sandy, but containing sufficient clay to give it the characteristics of a heavy loam. It contains a large amount of organic matter, which gives these soils their dark appearance and lasting fertility. There is but little difference in color between soil and subsoil; often there is no difference in color or texture to a depth of 36 inches. These soils are in places several feet thick, and grade into brownish heavy loams. Although this formation is heavy and poorly drained, the soils are by no means swampy. In dry seasons the surface soil cracks open, often to a depth of several inches. Often there may be small patches where there is a slight admixture of gravel on the surface, but these areas rarely exceed 1 or 2 acres in size. The percentage of gravel in such areas ranges from 10 to 30 per cent. It is well-rounded limestone gravel, with here and there a scattered pebble of some of the hard metamorphic rocks brought by the glaciers from the North. The frequent occurrence of large quantities of small land shells mixed with these soils was also observed.

The texture of typical soils and subsoils is given in the table following:

Mechanical analyses of Miami loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5006	West of West Carrollton.	0 to 10 inches	3.67	1.61	10.25	10.34	20.89	19.07	21.16	12.79
5005	Harshmanville, 1 mile NE.	10 to 30 inches	11.02	2.46	5.85	6.70	15.30	21.91	30.35	6.32
5007	Subsoil of 5006	do	5.35	2.16	8.08	7.26	22.73	21.73	22.82	9.82

But little timber is found on the Miami loam. There may be a slight fringe along the rivers, but that is all. Sycamore, oak, black

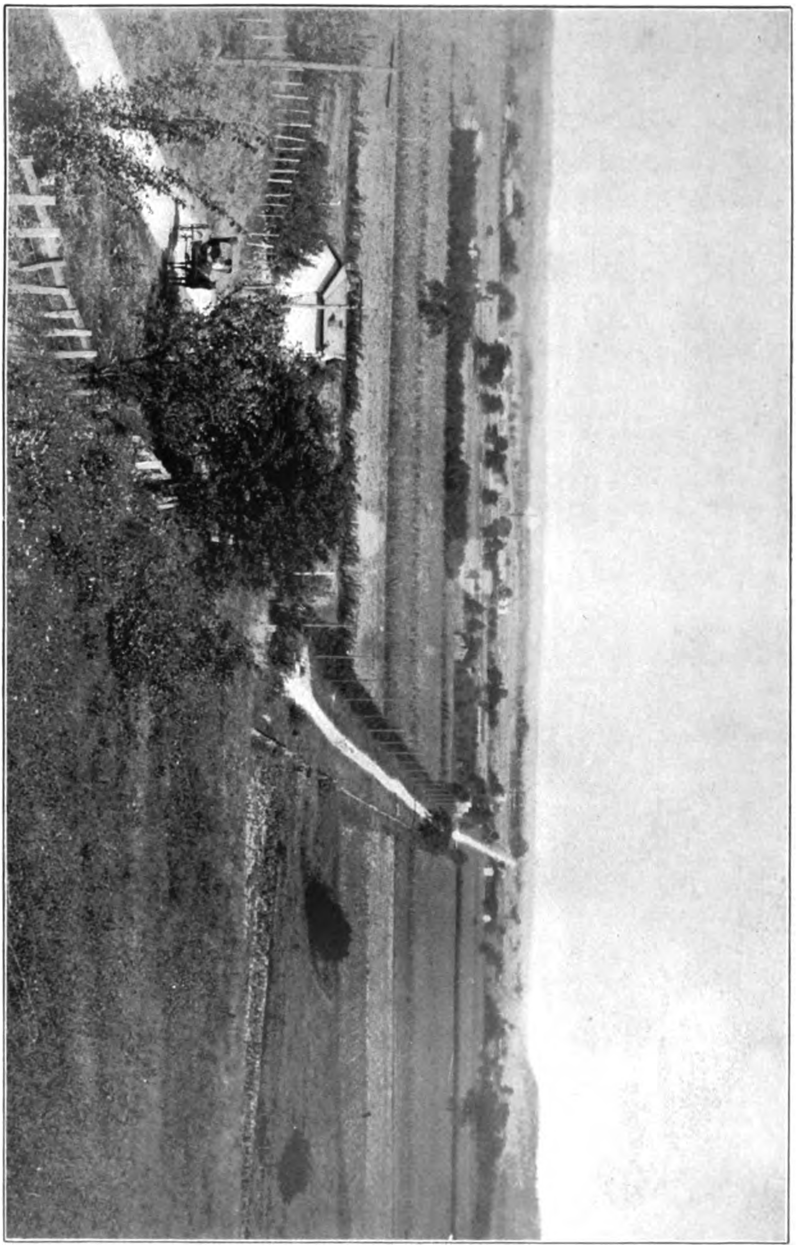
walnut, and hickory constitute the greater part of the present timber growth. As has been noted, these soils were the first to be cultivated, on account of their great natural fertility, and even now for some crops they are the best to be found in the county. Originally they were very strong and produced heavy crops, but now they are considerably worn and yet are really better adapted to general farming purposes. For corn they are ahead of the rest of the county, and from 60 to 90 or even 100 bushels per acre can be raised in a good year. In dry years wheat and timothy can be grown, but when there are frequent rains all crops are apt to be too weedy on these rich bottoms. Many large fields of broom corn are annually grown on the Miami loam soils.

Tobacco was formerly grown to a large extent on the soils of this formation, but with the increasing demands for a better quality this crop has been largely given up. The tobacco is heavy and dark and makes a rank growth, which is undesirable for filler purposes, but answers for shipping tobacco. The old-fashioned broadleaf and seed leaf are the principal varieties of tobacco grown on the first bottoms. The quality of the tobacco is even better than that raised on these same soils many years ago, but the dealers are unwilling to buy tobacco grown on these heavy "black lands," as they are called. In the vicinity of Dayton considerable attention is given to raising melons, vegetables, corn, and celery on the Miami loam. This soil is much in demand for growing corn, but not for general farming purposes, because the streams have a tendency to overflow, which is always considered a detriment even to the finest soils.

MIAMI GRAVELLY LOAM.

Another formation which occupies large areas in the river valleys proper is the Miami gravelly loam. This is generally known as the second bottom, and is considered the finest farming land in the valley. The principal areas are situated between the Great Miami and Mad rivers, and a few miles south of Dayton, east of the Great Miami River in Van Buren Township. There is also another large area in West Dayton, but it is largely covered by the city. In addition to these there are several other areas of a few square miles in extent. This formation may occur as a high first bottom, generally as a second bottom, or it may be a third or even a fourth bottom above the river beds. These river bottoms, or more properly speaking, terraces, are from 30 to 60 feet above the river level. When a number of successive terraces are found they rise from 5 to 15 feet, one above the other. Rarely five distinct terraces may be counted, but the most common occurrence of this formation is either as a high first terrace above the river or a rolling terrace 10 to 15 feet above the areas of the Miami loam formation.

The soils of this formation are derived from the great mass of glacial débris deposited over the country by the ice, but this material



GENERAL VIEW OF SECOND BOTTOM LAND (MIAMI GRAVELLY LOAM) SOUTH OF DAYTON.

has subsequently been considerably modified by the action of the streams which flow through the valley. These rivers and streams must have been greatly swollen during the close of the glacial epoch when they received the waters from the melting masses of ice from the country to the northward. The terraces certainly bear witness to the assorting and carrying power of these swollen rivers, for in every instance they are found to consist of great thicknesses of well-rounded and nicely assorted beds of gravel and sand. These terraces furnish large stores of gravel well adapted for road ballast, as the many excellent gravel roads of the county will testify. Many of the railroads have also taken advantage of these thick deposits of clean limestone gravel and thousands of cubic yards of this material are used

FIG. 5.—Section in Miami gravelly loam, showing loam soil overlying clay subsoil, grading into rounded gravel.

annually for grading their roadbeds. Although the terraces are composed largely of gravel, the soil is more or less mixed with sand and clay. The soil may then be described as a heavy, sticky, reddish-brown loam to a depth of 12 inches. This soil contains some sand, but there is sufficient clay to give it the properties of a heavy loam. Under the soils are found stiff, reddish-brown clay loams, quite similar to the subsoils of the clay uplands, but always containing a larger percentage of sharp angular quartz gravel somewhat less than one-half inch in diameter. The subsoil as we go deeper contains more and more gravel, until at 30 inches it grades into a mass of well-rounded gravel. Exposures of 30, and even 40 feet of well-rounded, stratified gravel underlying these soils were noticed in some of the old gravel pits above and below Dayton. (See fig. 5.) These gravel beds

insure perfect drainage conditions for these soils and render them warm and dry. On the surface there is a varying amount of well-rounded gravel from 2 to 5 inches in diameter. The gravel contained in the soil to a depth of 10 inches is seldom less than 15 per cent, and rarely does it exceed 40 per cent. Excessive amounts of gravel on the surface of these soils are only found in very limited areas. Often along the slopes, from one terrace to another, the gravel may be found coming to the surface in considerable quantities. Generally, the gravel is nearer the surface in the large area south of Dayton than it is in other extensive areas of this formation. None of the areas is subject to overflow from the rivers, even during the highest floods. These soils are variously spoken of as bottom lands, second bottoms, gravel bottoms, and gravel lands.

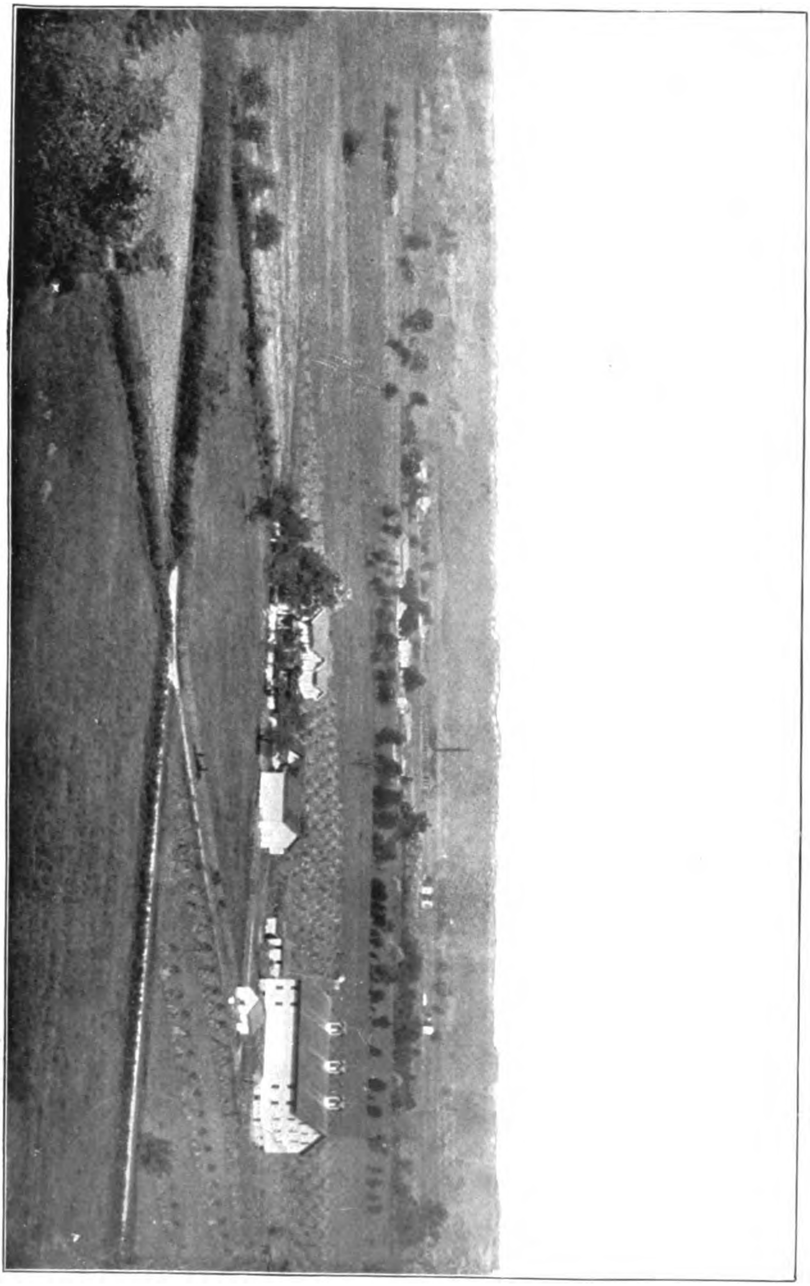
The mechanical analyses of typical samples are given in the following table:

Mechanical analyses of Miami gravelly loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5008	North of Dayton.	0 to 12 inches	2.49	5.51	11.23	9.36	17.66	15.58	25.59	12.95
5009	Subsoil of 5008	12 to 24 inches	2.34	17.64	14.60	10.06	9.90	6.19	13.00	26.53

These second bottoms were eagerly sought by the early settlers, for it was recognized that the soils were light, warm, and dry, and would produce double that of the cold, wet uplands. When discovered they were said to be covered with a thick growth of sugar maple, black walnut, many kinds of oak, ash, hickory, mulberry, elm, locust, buckeye, basswood, sycamore, cherry, hackberry, gum, and beech—trees which denote a rich, productive soil. But little now remains of the once extensive forest growth, and only scattered wood lots are seen which are mostly a growth of a few varieties of oak.

Corn, wheat, and tobacco are the principal crops, and, in addition, considerable truck is grown near Dayton on these loamy second bottoms. From 50 to 60 bushels of shelled corn per acre can be grown, and from 20 to 30 bushels of wheat is a good yield. In a favorable season clover does well, and considerable sorghum cane is raised in different parts of the valley. Many large market gardens are successfully operated near Dayton. These usually have two or more large windmills for pumping water to irrigate the small fields, and to enrich the soil large amounts of stable manure are brought from the city. The main truck crops are celery, cabbage, melons, tomatoes,



MIAMI GRAVELLY LOAM WITH MIAMI CLAY UPLAND IN DISTANCE.

beans, corn, together with small fruits and grapes. The soils of this formation are always in demand, and some of the best improved farms of the county are to be found on the gently rolling terraces. It was on these soils that the early cultivation of tobacco received such an impetus, and for a long time they were considered the finest tobacco lands of the valley, but with the ever changing demands of the trade they are not now so important as formerly. There are many large fields of tobacco raised each year, although the quality of the leaf does not compare with that grown on the clay uplands. Many assert that the crops grown on "gravel land" has a decided tendency to rust badly, but fully as many tobacco growers maintain that such is not the case. Nevertheless, for some reason, tobacco grown on any character of bottom land, whether gravelly or not, is subject to rust and does not make as desirable a filler leaf as that grown on the uplands.

MIAMI CLAY LOAM.

We have now come to the most important soil formation in the county—the Miami clay loam. This formation covers fully four times as large an area in the county as the combined areas of all the other formations, and if time had allowed the survey to be extended into adjoining counties a still greater extension of this same formation would have been found reaching for miles and miles in every direction. Frequently the roads extend a long distance through this formation without a change in the character of the soil, other than the slight changes depending upon the varying drainage conditions of the different fields. There are large areas in the northern part of the county that are the exact counterparts of equally large areas in the extreme southeastern or southwestern portions of the county.

The surface of this formation varies greatly in the different sections of the county. In the northern and central portions the formation is a broad, level, or gently rolling plain. In the other sections the surface is hilly and broken, although there are frequently interstream areas which are comparatively level for a considerable distance. In the level areas of this formation the fields are apt to be poorly drained, and formerly this was much more generally the case, but the opening of large ditches and the drainage of the fields by tile drains have put the lands in excellent condition, so that they are no longer spoken of as cold wet uplands. In the more hilly portions the drainage is well established and artificial drainage is unnecessary. Where the upland borders the valleys often there is a steep scarp of from 80 to 120 feet, but where the valleys gradually merge into the uplands a distance of several miles may be traversed before the general level of the upland is reached.

These soils are the weathered products of the heterogeneous mass of ground-up rocks which were left upon the surface of the county in

Glacial times. This deposit of Glacial débris varies from a few feet in thickness to upward of 100 feet, depending upon the inequalities of the original rock surface before the materials were deposited.

The soil proper of this formation may be classed as a light loam, uniform in texture and composition. It is a remarkably uniform soil, and is everywhere seen to be the same, whether found on the steep hillside or on the more level upland. It has a light, brownish-yellow color when newly plowed or when moistened by recent rains. When not stirred for several weeks in a hot, dry season it becomes almost white, and is often spoken of by the farmers as white clay. This character of material is found to an average depth of 10 or 12 inches. It is easy to till, as it is light and loose and readily dries after rains. The

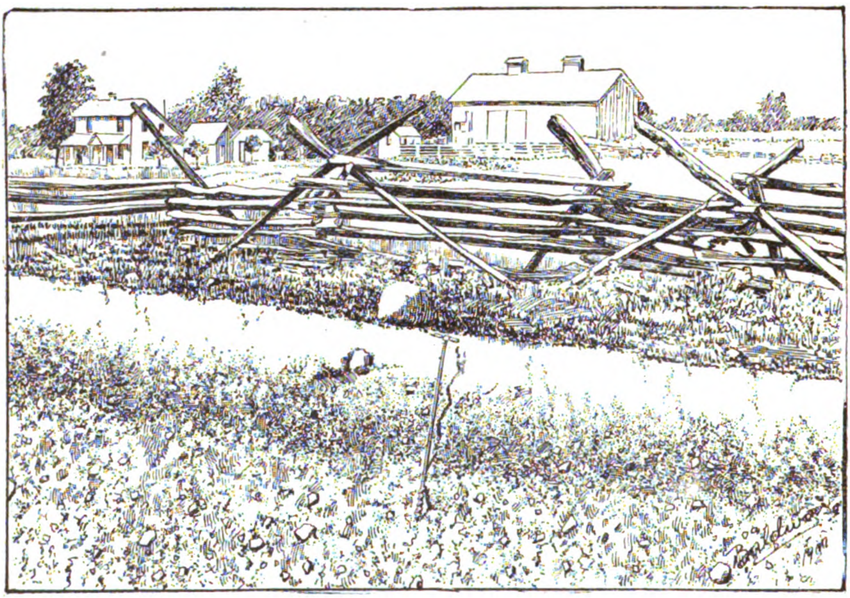


FIG. 6.—Section in Miami clay loam, showing light loam soil on stiff clay loam, grading into bowlder clay.

subsoil, beginning at a depth of 12 inches, is a heavy, sticky, red-brown clay loam which, when thoroughly dried, checks into small cubes closely resembling the stiff subsoils of the Miami gravel loam. The clay loam subsoil contain a much smaller percentage of small, angular quartz gravel, and in many localities it contains no gravel whatever. When these clay subsoils are free from gravel they closely resemble the alluvial deposits of the Red River in Louisiana and Arkansas. The depth of the clay subsoils of this formation is from 2 to 5 feet. (See fig. 6.) In the northern and in some places in the central western portions of the county the clay subsoils rest directly upon the glaciated and scratched surface of the Niagara limestones. In many other portions the subsoil at a depth of 3 or 4 feet passes gradually into a stiff

mass of clay filled with angular bowlders and pebbles and with occasional pockets of quartz sand and well-rounded, clearly stratified gravel. The pebbles and bowlders interbedded in the ground mass of clay generally have sharp corners and are often scratched, especially on one side. Exposures of this drab-colored mass of bowlder clay, as it is called by geologists, were noticed which had a thickness of 40 feet; again, at a depth of 18 or 20 feet, it was observed resting upon a bowlder clay somewhat similar to that in composition, but of a decidedly bluish color and with a slightly greater percentage of clay. There is usually a small amount of stones on the surface of the soils, but never enough to interfere with cultivation, for the bowlders above described have long been removed or so placed that the fields can be cultivated without great difficulty. The percentage of small stones on the surface varies from 5 to 20 per cent. These stones are fragments of limestone and angular pieces of the metamorphic series of rocks, such as granite, gneiss, etc.

The mechanical analyses of a number of soils and subsoils are given in the following table:

Mechanical analyses of Miami clay loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5014	Centerville, 2 miles SE.	0 to 12 inches	2.68	0.72	1.57	1.78	4.08	10.82	65.80	11.62
5012	Salem, one-half mile SW.	Brown loam, 0 to 12 inches.	3.86	1.28	2.83	3.46	11.36	11.40	48.40	16.89
5013	Subsoil of 5012	Stiff clay loam, 12 to 36 inches.	2.84	2.72	3.52	3.34	11.19	14.22	26.40	35.25
5017	Sulphur Grove, 1 mile E.	12 to 36 inches	3.12	1.31	2.49	2.49	8.64	13.11	31.11	37.37

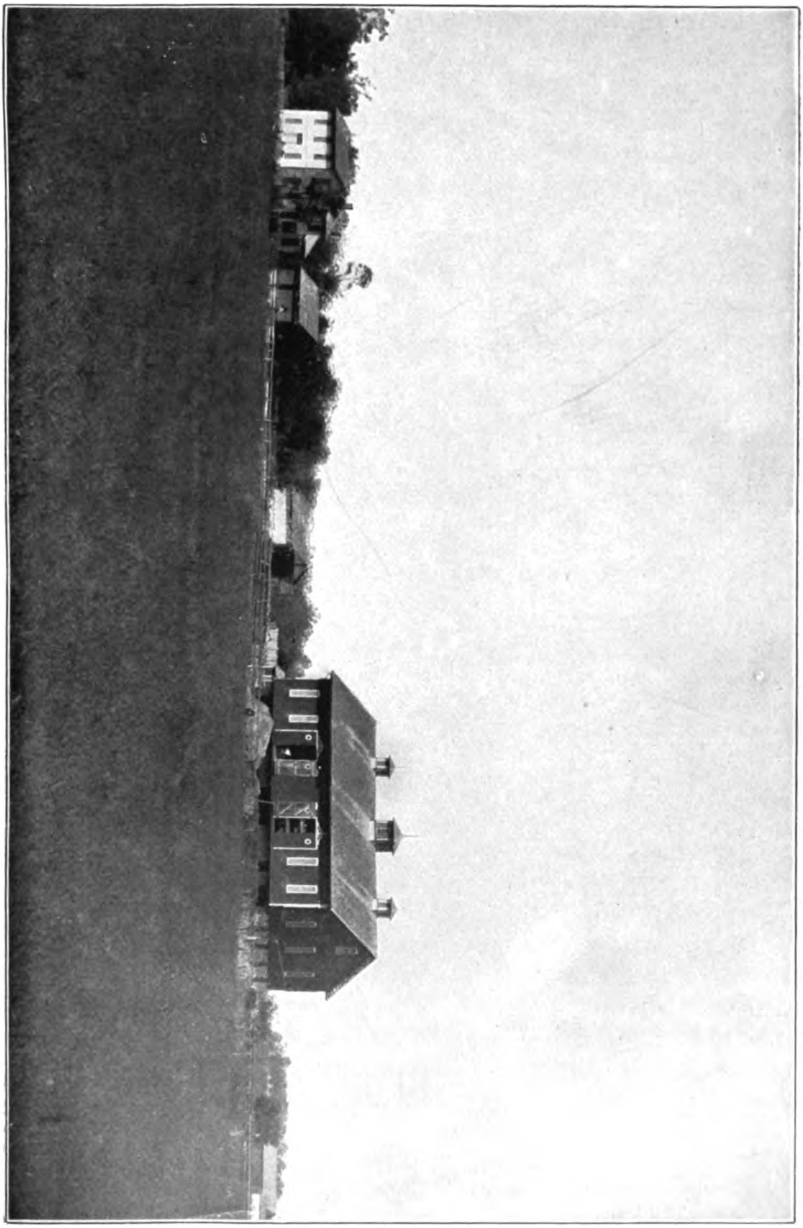
Although it has been stated that these soils are remarkably uniform, there are two areas which deserve special attention. These are a high hilly area a short distance southeast of Dayton, and another somewhat similar area a few miles northwest of Dayton, in Harrison Township. In these two localities there are several high hills which are composed to a great extent of large, rounded gravel filled with pockets of clean sharp sand and overlaid with soils, the exact counterpart of the soils of the typical areas of this formation. The only difference in these areas is that at a depth of 2 feet the subsoils are underlaid with gravel instead of a compact clay filled with angular bowlders. The drainage conditions of these two areas are the same as the Miami gravelly loam.

The Miami clay loam is called by various local names, which usually have some reference to the topography or soil conditions. A

common name is that of "sugar-tree land," on account of the prevalence of the sugar maple in the native forests. Again, they are called clay uplands or second bottoms, as distinguished from the lower river bottoms proper. Frequently they are called limestone soils, from the beds of limestone which closely underlie them; again they are called white clays, or, if deep plowing has brought some of the subsoil to the surface, they are termed red clays. In the more level portions of the area, where the timber growth is largely beach, the name beech land is used. When these lands were first explored they were covered with a thick growth of sugar and soft maple, basswood, beech, black walnut, poplar, wild cherry, white and blue ash, several varieties of oak, black gum, elm, hickory, buckeye, and ironwood. There is still considerable timber standing on the uplands which can be seen skirting the horizon in every direction. From an eighth to a tenth of the entire area is still forested with the clean open forests characteristic of this section of Ohio. Almost every farm has a few acres of woodland which are used as pasture for the cattle and from which the supply of firewood is obtained. When the woods consist largely of sugar trees, the sugar house is generally found somewhere within its borders, and in the spring a good profit is realized from the sale of the maple sirup or maple sugar made from the evaporated sap.

While the Miami clay loam is not the most fertile soil found in the county, still it is good strong land, capable of being made very productive, and is durable and lasting. It will produce on an average from 40 to 60 bushels of corn per acre, but a yield of 75 or 80 bushels is not uncommon. Wheat will make from 20 to 30 bushels, but in 1900, owing to unfavorable conditions, the crop was a complete failure, there being very few farmers who even recovered their seed wheat. Oats do well on these soils, while clover and timothy make fair crops, but are not extensively raised. In the rotation practiced, corn is usually followed by wheat with clover sown in the spring; the following spring the clover is used for hay, and this is in turn followed by corn. This is the usual three-year rotation, but other rotations may vary somewhat, depending upon the number and size of the fields in the farm. When tobacco is grown it usually follows the corn crop. Considerable millet is grown on the uplands, but it is generally grown as a catch crop when other crops for some reason have failed. Many fields of sorghum cane are grown on the uplands, and it is generally considered that the crop does very well. Fruits also make a fine growth on the clay uplands, and every farmer has a small apple orchard and a few pear trees and cherry trees. Occasionally peach orchards are seen, but they are not generally successful on the more level uplands.

Tobacco is the one crop which seems to succeed the best of all on the clay loams of the uplands, and each year large quantities are harvested. On almost every farm will be found 3, 5, or 8 acres of tobacco, while many farmers have from 10 to 30 acres in this crop. Tobacco



GROUP OF FARM BUILDINGS ON MIAMI CLAY LOAM.

grown on the uplands has good body, good sweating properties, is fine fibered, and elastic.

MIAMI BLACK-CLAY LOAM.

Like the soils of the formation just described, the Miami black clay loam is found occupying portions of the upland. The largest continuous areas are in Clay Township, in the northwestern part of the county, but there is no township which does not contain several small scattered areas of this formation. These areas are always found more extensively developed in the more level portions, and it is the level or gently rolling character of the county which accounts for their occurrence. Upon close examination, they are found to occupy small depressions on the surface of the upland. When the ice retreated northward, at the close of the glacial epoch, these small depressions on the surface of the drift were gradually filled with standing water. The accumulation of decaying vegetable matter and the slight wash from higher ground has formed the soils of the Miami black clay loam. The soils, then, of this formation are the result of the imperfect drainage conditions of these old depressions on the surface of the glacial débris of ground-up rock and clay or drift. When the country was discovered many of the areas of this formation were covered with several feet of water, which did not drain off the entire year. Mention is made [1] of one of these swamps in Butler Township, which was thickly covered with trees. In this swamp large flocks of wild ducks and geese were swimming about. Other swamps are mentioned, which were regular peat deposits and quagmires. All of these wet lands were held in low esteem. Since that time they have been thoroughly drained by deep wide ditches and by field drains of various sorts, until now they are capable of cultivation and are perfectly dry, but little evidence remaining of their former swampy condition.

The soils of this formation are easily recognized by their black color, which in dry seasons become somewhat ashy. The top soil consists of a heavy, black, sticky clay loam, which is hard to cultivate on account of its clayey nature. The soil has a tendency to bake hard and to crack open in dry seasons. Often there is no change in the character of these soils to a depth of 2 feet; again, the subsoil may be a trifle heavier and more tenacious. At a depth of 3 or 4 feet, or occasionally at a less depth, they grade into stiff yellowish clay loam. This is undoubtedly the same material as the subsoils just described, only the amount of organic matter is somewhat less, and the soils are hence less discolored. At greater depths than 3 or 4 feet the subsoils are the same as those of the Miami clay loam. There is a slight admixture of angular stones and pebbles upon the surface, but the amount seldom exceeds 20 per cent.

The following table contains mechanical analyses of typical samples of both soils and subsoils of this formation.

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[1] History of Montgomery County, Ohio, 1883.

Mechanical analyses of Miami black clay loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5023	Stringtown, 2 miles E.	Heavy black loam, 0 to 12 inches.	8.93	.46	2.19	2.38	6.16	9.30	54.43	15.30
5021	West Baltimore, one-half mile N.	Heavy loam, 0 to 10 inches.	6.86	1.40	2.14	2.69	7.34	8.29	54.14	17.14
5024	Subsoil of 5023	12 to 36 inches	5.67	.74	2.30	2.15	6.38	7.52	53.31	22.29
5022	Subsoil of 5021	Black clay loam, 10 to 36 inches.	4.87	.72	1.94	1.56	4.87	7.56	52.52	25.90

Originally these areas were covered with a heavy forest growth, consisting of much the same growth as that found on the Miami clay loam. Walnut, beech, and elm were much more abundantly found. Before drainage, many of these places were miry and were carefully avoided, but now they are all cultivated and are fairly productive. They make good crops of corn and tobacco, but clover does not succeed well nor does wheat, which puts on too heavy a growth of straw and is apt to lodge. The yield of the various crops on these soils is not essentially different from that of the Miami clay loam in favorable years. Good crops of tobacco are also grown on these soils after they have been cropped a few years. It is said that when these soils are fresh the tobacco is apt to fire in a dry season and be rank and coarse. In good seasons crops are grown that will compare very favorably with the best of the clay upland tobacco. It is said that where the areas of these black clay soils come in contact with the yellow clay loam soils the mixture of the two soils will produce a fine quality of Zimmer Spanish tobacco. Although the areas of this formation were considered very poor, on account of their imperfect drainage, they now rank as productive soils and command a fair price. They are called black lands and bottom lands, although they probably occupy the highest portions of the county.

MEADOW.

This name has been used to describe a condition of the soils very generally noticed in the county, rather than any particular type of soil. Usually occurring in narrow strips along the small streams, they are seldom over a few hundred yards in width. Wherever the stream valley widens out considerably and is characterized by a certain definite character of soil, the soil is classified and the area shown on the map, but the meadows are the smaller stream bottoms, wet and swampy, and uncultivated. Generally, the soils of the meadows are sandy and mixed with decomposed matter, and if thoroughly drained would make fertile land, but in their present condition they are used for pasture, or occasional crops of meadow grass may be cut off them. If drained they would produce good crops of corn and also good crops of timothy hay.

SOIL SURVEY OF CECIL COUNTY, MD.

By CLARENCE W. DORSEY and JAY A. BONSTEEL.

INTRODUCTION.

Cecil County is the most northern of the Eastern Shore counties of Maryland. It lies between 75° 46′ and 76° 14′ west longitude and 39° 21′ and 39° 43′ north latitude. The greatest width is 25 miles, while the length north and south is practically the same. On its northern border and for a short distance along its eastern boundary the county comes in contact with Pennsylvania. Delaware lies east of the greater part of the county. The broad Susquehanna River and Chesapeake

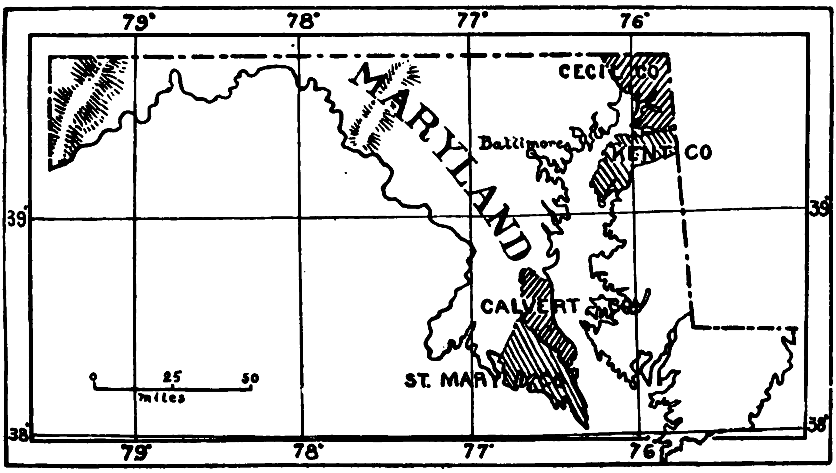

FIG. 7.—Sketch map of Maryland, showing area surveyed.

Bay bound the county on the west, while the Sassafras River separates it from Kent County on the south. The area of the county, exclusive of the broad waterways, is about 375 square miles (240,000 acres). (Fig. 7.)

PHYSIOGRAPHY.

Cecil County is one of the few Maryland counties that contain within their borders two essentially distinct types or classes of topography. These two different classes are found typically developed in the northern and southern parts of the county, while in the central portion there is a gradual blending of the two, consequently the distin-

guishing features of both are lost. The northern part of the county, including about one-third of the entire area, belongs to the prominent physiographic division of the United States known as the Piedmont Plateau. The southern part of the county belongs to the Coastal Plain region, which extends as a wide border along the Atlantic Coast States.

The Piedmont Plateau region in Cecil County consists of a broad, rolling plateau, through which the largest streams have carved deep, narrow, winding valleys. Along the Susquehanna the plateau or upland rises abruptly 200 or 300 feet above the river. The plateau varies in elevation from 200 to 350 or 400 feet above sea level, but an elevation of 540 feet is reached a short distance southwest of Rocksprings. Along the Susquehanna River and larger streams the country is hilly and broken, but away from the streams the gently rolling character of the plateau is quite marked. The most level part of the plateau is in the north central part of the county, in the neighborhood of Brick Meeting House. The greater part of the drainage of this upland region is carried away by the Big Elk and Little Elk creeks, the Northeast and Little Northeast creeks, Principio and Octoraro creeks. Of these creeks the Octoraro is the only one which empties into the Susquehanna. The other creeks flow into the Chesapeake Bay, although they become greatly distended when they reach the comparatively low areas of the Coastal Plain region.

The Coastal Plain in Cecil County covers the greater part of the county, and is characterized by broad necks of land separated by wide tidal rivers. Along the junction of the upland with the Coastal Plain country there are large, rounded, gravel hills rising to an elevation of over 300 feet. These also form the backbone of Elkneck. These hills merge gradually into long, sloping terraces, which extend to the broad tidal rivers. In the lower part of the county the broad river necks stretch for miles, with gently rolling surfaces rising from 60 to 80 feet above tide water. The streams on these broad necks are small and only a few miles in length, broadening into wide tidal rivers in their lower courses. The drainage on these necks is not thoroughly established, although there are no undrained areas of any great extent. On Elkneck the streams are short, and during the greater part of the year are dry on account of the gravelly nature of the soils. In the area along the margin of the two physiographic divisions of the county the streams flow rapidly, cutting through the covering of sands and clays of the Coastal Plain into the harder rocks of the Piedmont Plateau.

GEOLOGY.

As the surface features of the county readily fall into two widely divergent classes, so the geologic formations are separated into two systems, representing the oldest, most altered series of rock, as well as the most recent geologic deposits. (For geological sections across

the county, see figs. 8 and 9.) The rocks of the northern part of the county embrace those which are characteristic of the Piedmont Plateau from New England far into the Southern States. They consist of granites, schists, gneisses, and serpentines cut by intrusive masses of diabase and gabbro. These rocks represent the older portions of the earth's surface, and they have been greatly altered and folded by the long-continued processes of metamorphism. Just when they were formed and what was their original composition have not been satisfactorily explained by geologists, although the work of recent

FIG. 8.—Profile from Elk River northeast through Grays Hill: *Sl*, Sassafras loam; *Ns*, Norfolk sand; *Sc*, Susquehanna clay; *C*, Cecil clay; *Ec*, Elkton clay.

years places the time of their origin at a much later date than formerly. The gneiss and schist for the most part are supposed to have originally consisted of sedimentary deposits.

The rocks of the Piedmont Plateau contain many important economic products. The exposures of granite along the Susquehanna have for many years been extensively quarried at a number of places, the chief of which are at Port Deposit and Frenchtown. Both of these towns annually place on the market large quantities of fine stone suitable for building and other purposes. There are many other smaller quarries in the county which furnish considerable stone for

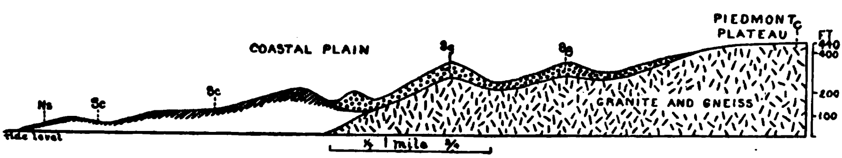

FIG. 9.—Profile from tide level to Piedmont Plateau, northeast of Charlestown: *Ns*, Norfolk sand; *Sc*, Susquehanna clay; *Sg*, Susquehanna gravel.

local use. Formerly there were soapstone and serpentine quarries, as well as flint and spar mines, which were worked, but none are in operation at present. At one time iron ore and large quantities of chrome were mined in the northern part of the county, but these mines have long been idle, for they are too "lean" to compete with the richer deposits found elsewhere. Gold has also been found in small quantities, and at different times its discovery caused much excitement, but little or nothing came of these finds, and they were soon forgotten. This section abounds in rocks admirably suited for making excellent roads and turnpikes, but little systematic effort has

been made in this direction. The deposits of gabbro, the hard, fine-grained, bluish rock found so extensively in the northwestern part of the county, are best adapted to road making, but good, durable roads can be made from almost any of the rocks in this section.

The rocks of the Coastal Plain series of formations in the lower part of the county consist principally of unconsolidated beds of gravel, sand, and clay. In some places these have become indurated, and local beds of sandstone and ironstone are found. From an economic standpoint the beds of highly colored clays are the most important. They furnish valuable deposits suitable for making brick and pottery, and also contain deposits of iron ore. The gravel, where it occurs in considerable quantity, makes good road material, and it is utilized for this purpose in the central part of the county. The deposits of the Coastal Plain series of rocks range in age from the Jurassic to the Pleistocene, or most recent geological epoch.

CLIMATE.

While there are at present no stations of the United States Weather Bureau situated in Cecil County, continuous records were kept at Woodlawn for a number of years, and from these and from records of stations in adjoining counties the following table[1] of the temperature and rainfall has been compiled. The other stations are situated at Darlington, Harford County, and Chestertown, Kent County, and at Newark, Newcastle County, Del. None of these stations are more than a few miles distant from Cecil County. The figures given are the averages of the Woodlawn and the three outside stations mentioned. The extreme range of temperature from records of a long number of years is 110°, or from −12° in the winter to 98° in the summer. The last killing frost in the spring rarely occurs later than the third week in April, and the first severe frost has not occurred before the 8th of November. Doubtless there is some difference in the temperature and rainfall records between the northern uplands of the county and the lower river beds of the southern part, but the records are not sufficiently complete to determine these.

Climatological data for Cecil County, Md.

Months.	Mean monthly temperature.	Mean maximum temperature.	Mean minimum temperature.	Mean daily range of temperature.	Highest recorded temperatures.	Lowest recorded temperatures.	Rainfall records.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Inches.*
April	51	61	42	20	94	20	3.7
May	62	72	53	20	94	37	4.3
June	71	81	61	20	94	42	3.9
July	75	84	67	17	98	50	4.3
August	74	83	63	21	98	49	5.7
September	68	76	58	19	97	36	4.0
Annual	54	63	45	18	98	−12	47.8

[1] Maryland Weather Service, vol. 1, 1899.

AGRICULTURAL CONDITIONS.

As might be expected from the diversified surface, the agricultural conditions are quite distinct and characteristic in the respective portions of the county. The great range in the character of the soils, from those absolutely barren to the most productive, is probably the greatest factor in the diversified agricultural conditions. While formerly there were many large farms in the county, these have been divided and subdivided until now the average-sized farm does not contain more than from 100 to 120 acres. These farms vary greatly in value, according to the improvements and character of soil. In some of the poorer portions unimproved land brings but a few dollars per acre, and there is no great demand for it at any price. In the better sections good farm land brings from $40 to $75 per acre. In the more prosperous farming sections the improvements are good and prove the thrifty and industrious character of the farmers, but in the gravel and clay hills of the central part the improvements are poor, consisting of ragged, dilapidated fences, small dwelling houses, and patched-up barns and sheds. In the good farming districts the dwelling houses are comfortable, some of them being quite pretentious, while the barns and other buildings are in keeping with the general character of the country. Neatly trimmed hedge fences form an attractive feature of the farm surroundings. Many of these farms are tilled by the owners. This is especially the case in the northern part of the county, but there is also a large number of farms which are in the hands of tenants who are not greatly interested in improving the farms and in bringing them to a high state of cultivation.

A large portion of the county is still forested and uncultivated. While originally the entire county was thickly timbered with various kinds of hard-wood and soft-wood trees, none of the original growth is left standing. In many parts the light timber growth has been removed every few years regularly for making charcoal and also for use in smelting the ores which were formerly extensively mined.

Wheat, corn, timothy, and clover are the main crops, and these are grown over the entire county. Truck is grown to some extent, but in the northern central part, growing late crops for canning purposes has for a long time been an important industry. Tomatoes and corn are the principal crops grown for this purpose, and for a long time Cecil and Harford counties have ranked among the prominent tomato-canning districts of the country. Competition with the Middle Western States has somewhat diminished the proportions of this industry, but it still is a large source of revenue to the farmers and to the hands employed during the growing season. The canneries are all small, situated short distances apart, and are only run for a few months in the late summer and the early autumn. If the small, scattered canneries were grouped into larger and better equipped factories, more centrally located, operated from early spring until late fall, and were prepared to can a greater variety of products, they could be much more profitably oper-

ated. At present the profits are divided among a number of small, poorly equipped plants, which tend to cripple the industry rather than to encourage it.

The fruit industry of Cecil County also deserves mention, as large quantities of peaches and pears are annually placed on the markets. Although the cultivation of apples and cherries is less, these, as well as small fruits, are grown both for home consumption and for the markets.

The market advantages of Cecil County are good, for with the rapid and abundant transportation facilities the county enjoys, the products can soon be placed on sale in the large Eastern cities. The county is midway between Baltimore and Philadelphia, and these cities consume the greater part of the farm products. There are two main lines of railroads which cross the county between these cities, in addition to branch lines of one of these roads, which furnish an easy outlet for the northwestern part of the county. The southern part of the county, while it has no railroads, possesses fine waterways, and consequently cheap water transportation to Baltimore and Philadelphia. Several points in the southern part are reached by daily steamboats as well as by sailing vessels of various descriptions.

No systematic efforts have been made to equip the county with roads built on scientific principles, and the majority of the roads are not in very good repair. Some of them have been made of broken stone and gravel, and these are above the general average of country roads. Others, again, are deep and sandy, making the hauling of heavy loads over them almost impossible at any time of the year. The roads are all free, are maintained at the expense of the county, and connect all of the towns and villages, with frequent intersecting cross-roads.

SOILS.

The soils of Cecil County range from barren to exceedingly rich and productive lands, and from coarse sandy soils to stiff, intractable clays.

The soils occupy about the following areas:

Areas of the different soils.

Soils.	Acres.	Per cent.	Soils.	Acres.	Per cent.
Cecil loam	52,600	21.9	Susquehanna clay	11,000	4.5
Sassafras loam	50,500	21.0	Cecil mica loam	10,000	4.1
Norfolk sand	46,600	19.4	Elkton clay	7,000	2.9
Susquehanna gravel	45,600	18.7	Conowingo clay	3,000	1.2
Cecil clay	12,500	5.2	Conowingo barrens	2,000	.8

CECIL LOAM.

The Cecil loam constitutes a type of soil characteristic of portions of the Piedmont Plateau, not only of Cecil County, but also of large

areas of northern central Maryland and adjoining States as far south as the Carolinas. Beginning at the gorge of the Susquehanna River, in the western part of the county, it continues in an unbroken area several miles in width to the Pennsylvania line on the eastern border. Along its southern border it presents a ragged outline, being buried under the outlying gravel deposits of the Coastal Plain formations. On the northern boundary these formations merge into the other formations of the Piedmont Plateau, with no sharp lines of demarcation of the soils or decided change in the surface features of the country.

The topography of this formation partakes largely of that of the Piedmont Plateau. Along the Susquehanna there is a steep descent of 200 feet or more from the upland to the river bed, steep, rocky

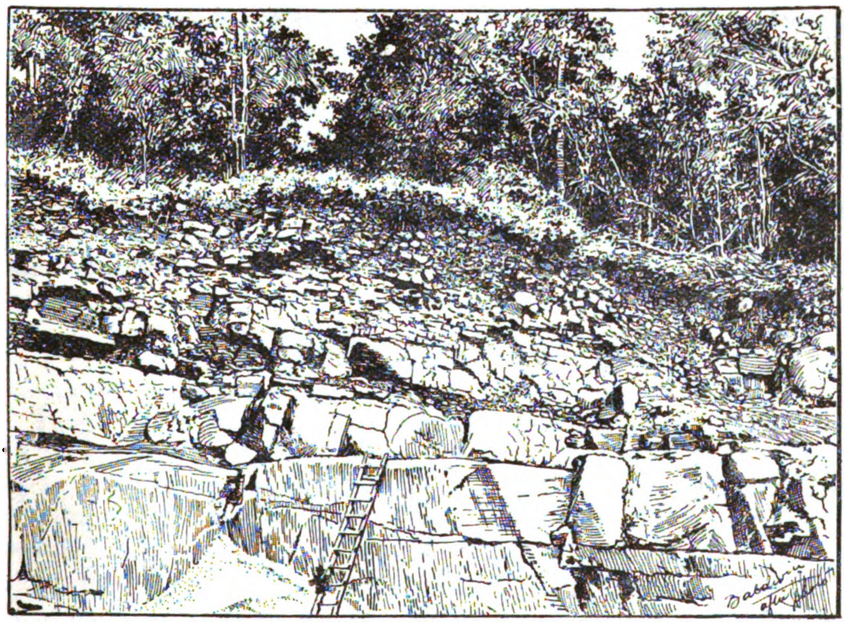

FIG. 10.—Weathering of granite into Cecil loam, near Frenchtown.

hills characterizing this portion of the formation. The remainder of the formation is a rolling upland, broken by the steep, narrow valleys of the various streams which cross it. Many parts of this formation are those which have been referred to as the most level of the Piedmont Plateau in Cecil County. The drainage of this entire area has for a long time been thoroughly established, so that there are no swampy areas; for the formation is not only well drained but also well watered by the many small streams which traverse it in a southerly direction.

The Cecil loam is derived from the slow weathering of the granites, gneisses, schists, etc., which occur in the Piedmont Plateau. (See fig. 10.) Situated south of the limit of ice action during glacial times, the

slow processes of subaerial decay have had ample time to accumulate a soil covering, shallow or deep, depending on the location with reference to the washing influence of rains. These residual soils are all derived from the rocks which underlie them, or at most have been transported but very short distances. The soils consist of yellow and brown loams, slightly sandy, and about 10 inches in depth. The sand consists generally of sharp, angular grains of quartz, and frequently small bits of the undecomposed granite or gneiss may be found mixed with the soil particles. The subsoils are lighter in color and contain a greater percentage of clay. They may be classed as light, yellow-clay loams. Generally, these clay loams have a depth of 36 inches or more, but they often grade into loose masses of decomposed gneiss or granite at a depth of 30 inches, or occasionally at a depth of even 20 inches. In places the soil covering has a depth of several feet, but these are rare occurrences. On the surface there is usually present an appreciable amount of broken quartz and occasionally pieces of granite, gneiss, schist, gabbro, or any of the rock formations from which the soils are derived. Although the amount of stones may at times equal 40 per cent, generally the amount is much less and does not seriously interfere with cultivation. These stones range from one-half inch to 6 inches in diameter.

The following table gives the mechanical analyses of soils and subsoils of typical samples of Cecil loam:

Mechanical analyses of Cecil loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4029	Providence, 1 mile SW.	0 to 12 inches	5.55	3.02	5.74	12.64	14.92	13.90	32.96	11.32
4232	Farmington, 2 miles NE.	Yellow loam, 0 to 6 inches.	5.18	3.36	8.52	6.26	14.10	11.95	31.67	19.32
4030	Plumpoint, 1 mile SW.	12 to 30 inches	3.76	2.21	5.57	4.18	11.91	13.21	40.22	19.27
4233	Subsoil of 4232	Stiff yellow loam, 6 to 24 inches.	4.81	4.54	10.01	6.74	13.79	11.61	27.19	21.01

These soils are classed as good farm lands, and, while they are not naturally strong soils, they can by careful management be made very productive. Generally, they are deficient in organic matter, but this can be remedied by liberal applications of well-rotted stable manure or by the plowing under of green manure. As now cultivated too much money is expended for commercial fertilizers. By saving and applying stable manures these soils could be brought to a higher

state of productiveness than is attained by the use of often inferior brands of commercial fertilizers. Originally these soils were thickly covered with a heavy growth of timber, embracing all the common hard-wood varieties. The greater part of the area is cleared and under cultivation.

Tomatoes are grown on this soil in large quantities for canning purposes. Almost every farm, especially in the neighborhood of Risingsun and Zion, has a field of several acres each year in tomatoes. On account of the loamy condition, these are probably the finest corn soils in the county, and it is said that from 40 to 60 or even 80 bushels per acre can be grown. Wheat produces well, from 20 to 25 bushels being a good average crop in favorable seasons. Fifty bushels of oats can be harvested in good years, and clover and timothy make good crops. For many years Cecil County had a reputation in Baltimore markets for the fine quality of hay it produced, and it was on Cecil loam and Cecil clay that it was principally grown. Mixed clover and timothy seed are sown, but the clover rarely lasts longer than one year. The usual rotation practiced on these soils is wheat two years, followed by timothy and clover, which usually lasts two years, then corn, after which again comes wheat. When oats or tomatoes are grown the five-year rotation is varied somewhat, and occasionally the timothy is allowed to stay two years after the clover fails. This depends somewhat on the effect of the winter on the crops. Lime is applied to these soils and the good effects are noticed for several years afterwards. It is often observed that the lime has the effect of sweetening the soils and checking foul or rank growth.

The farms on these soils are usually comparatively small, and are in most cases tilled by the owners; hence they are kept in good shape and the people are in a generally prosperous condition. Some of the best improved farms of the county are located within the limits of this soil formation.

CECIL CLAY.

This formation, like the one just described, is found in the Piedmont Plateau region of Cecil County. The formation occurs in several areas scattered over the northern half of Cecil County. There are 11 of these areas, but the largest and most important are situated in the extreme northern part. The surface of the Cecil clay is probably more rough and broken than the Cecil loam, although there are some areas where the gently rolling character of the country is a rule. The broken and hilly areas of this formation are along the Susquehanna River and the Octoraro and Conowingo creeks. A few of the smaller areas of this formation form prominent hills in the Coastal Plain part of the county. Doubtless these hills were once covered by the gravels which cap the surrounding hills, but subsequent erosion has removed

this coating and they are now isolated areas entirely surrounded by the unconsolidated sands, gravels, and clays of the Coastal Plain. Grays Hill, 2 miles northeast of Elkton, furnishes a striking example of the isolated occurrence of this formation. This hill rises considerably over 150 feet above the surrounding country, which consists of broad terraces and low, marshy areas characteristic of this section of the Coastal Plain country. Fig. 8 (p. 105) shows clearly the relations of Grays Hill to the surrounding country.

These soils are also residual, being derived from the rocks which underlie them. The Cecil clay is for the most part derived from the weathering of the hard, igneous rocks, such as gabbro and diorite. These are dark-colored rocks, which weather comparatively slowly into characteristic spheroidal masses. These large, rounded bowlders are thickly scattered over the surface in some places in the Cecil clay. These stony areas are quite abundant on the upland just east of the Susquehanna River. Here the bowlders are so thickly strewn over the ground that fields of several acres are often uncultivated on account of them. They vary from a few inches to many feet in diameter and are often spoken of as "niggerheads."

The soils of the Cecil clay consist of heavy reddish loam, to an average depth of 10 inches, underlaid by red clay loam, which grade into stiff red clay. These soils are easily distinguished by their deep red color when in a moist condition. They are seldom over a few feet in depth and pass into broken pieces of gabbro and other rocks, from which they are derived. Generally there is a trace of broken quartz fragments scattered on the surface and mixed with the soils. Often there are small amounts of broken pieces of angular stone, rarely exceeding a few inches in length. These soils are much heavier than the Cecil loam and rank as strong clay soils, capable of standing hard farming, and also capable of being brought to a high state of productiveness. While the soils of this formation are generally quite uniform wherever found, the areas northeast of Brick Meeting House and east of Appleton partake somewhat of the nature of the soils of the serpentine clay (Conowingo clay) as far as their productiveness is concerned. There is doubtless some mixture with the serpentine clay, but as they more closely resemble the Cecil clay in texture and general characteristics they have been correlated with this formation.

The Cecil clay soils are generally classed with the Cecil loam as regards fertility, but by proper cultivation they can be made far more productive, and they are not so easily exhausted. It is said that one-half of the fertilizers necessary on the Cecil loam will suffice on these soils. Lime is used with excellent results, and commercial fertilizers, especially phosphates, are used in addition to frequent applications of stable manures.

The Cecil clay is well adapted to wheat and grass and produces large crops. Wheat will yield from 20 to 30 or even 40 bushels per acre in good years, and from 1 to 2 tons of timothy and clover hay can be harvested. From 50 to 60 or even 80 bushels of corn can be grown in favorable years, and yields of from 50 to 60 bushels of oats are reported. Tomatoes for canning purposes also produce well on these strong red clay soils, and from 200 to 400 bushels per acre can be grown with careful treatment and with favorable weather conditions. Apple trees make a healthy growth and bear well, but peaches and pears do not succeed. The farms are seldom large in this formation, but are improved, well kept, and indicate a generally prosperous condition.

CECIL MICA LOAM.

Like the formation just described, the Cecil mica loam also occupies an area in the rolling uplands of the Piedmont Plateau. There is but one occurrence of this formation in Cecil County, and that is along the northern border in the eastern part, where Maryland comes in contact with Pennsylvania on its eastern as well as northern border. This area is nearly 10 miles in length, and from 1 to 2 miles in width. The surface is rough and broken along Big and Little Elk and Christiana creeks; otherwise it is level or gently rolling. The uplands may rise from 200 to slightly over 400 feet in elevation.

The soils are also residual, having been derived from the decomposition of gneiss and schist, which contain, among other rock-forming materials, large quantities of mica. In the soils this mica appears in broken fragments, from the tiniest bits to particles of over a half inch in diameter. It is so abundant as to make the soils fairly sparkle in the sunlight, and on the soft dirt roads it floats away in the breeze with other dust particles. This feature has given the name to the soils, and they are commonly referred to as the red and white isinglass lands. The soils of this formation are light loams, lighter in texture than the Cecil loam, and they generally have a brownish or yellowish-brown color. They contain considerable sand, but are mostly composed of silt with small amounts of clay. The subsoils, from a depth of 10 to 30 inches, consist of reddish-yellow clay loam, which also contains a large percentage of finely divided mica of the muscovite variety. In texture the subsoils differ little from the soils, although they may contain a slightly increased percentage of silt. At an average depth of 30 inches the subsoils grade into the loose, decomposed gneiss, granite, schist, or whatever rock the soil is derived from. These soils are always warm and dry, and possess excellent underdrainage.

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The mechanical analyses of typical soils and subsoils are given in the table following:

Mechanical analyses of Cecil mica loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4222	Lewisville, three-fourths mile S.	Brown micaceous loam, 0 to 10 inches.	4.70	1.72	10.87	5.87	17.64	15.64	35.10	8.59
4223	Subsoil of 4222	Yellow loam, 10 to 36 inches.	6.86	2.69	6.44	5.26	22.41	14.20	29.16	12.78
4227	Appleton, 2 miles NW	Yellow loam, 8 to 36 inches.	4.07	4.75	7.93	4.92	10.13	9.24	42.93	15.50

These soils compare favorably with the Cecil loam, as far as their productiveness is concerned. They are naturally fertile; but they must be managed with care or their fertility is soon lost. They contain some quartz rock and broken pieces of gneiss and schist on the surface, but not so large an amount as the Cecil loam. Generally, they are mellow soils, easy to till, and respond quickly to the applications of manures or commercial fertilizers, such as tankage, ground bone, and phosphates.

Corn, wheat, and grass are grown on these soils, and the yields equal those of the Cecil loam. From 15 to 25 and 30 bushels of wheat, 45 to 60 bushels of corn, and 1 to 2 tons of hay are the crop yields in favorable seasons. Tomatoes and corn are grown for canning purposes. The crop rotations practiced are practically the same as on the other Cecil soils. As a general rule, small, well-improved, and carefully cultivated farms are found in this formation.

CONOWINGO BARRENS.

We now come to a class of residual soils occurring on the uplands of the Piedmont Plateau, which, although not differing greatly in texture from the soils just described, are found to be well-nigh worthless when their productiveness is considered. This is the type of soil known as the Conowingo barrens. Four small areas are found in the extreme northwestern corner of Cecil County. Two of these areas are of some size, but the others contain only a few acres. The largest of these areas begins at the Susquehanna, a half mile north of Conowingo, and continues northeast to the Pennsylvania boundary. The other areas are situated near by. All of the areas of this formation are rough and hilly. Conowingo and Octoraro creeks flow through both areas, which accounts for the rough and broken surface of the country.

This soil is derived from the weathering of serpentine, which is an altered eruptive rock of a dark greenish color. The soil generally is a light-yellow or whitish-looking loam, but in places it is almost black. The top soil occasionally has a depth of 8 or 10 inches, and is underlaid by a yellowish-brown loam subsoil to a depth of 36 inches. The soil is generally much shallower, and in the case of the barren hills of this formation the rocks are devoid of any trace of soil covering except that caught in the pockets and crevices of the rocks. Frequently, even on level or lightly rolling areas, the soil covering may not exceed a few inches in depth. These soils, as seen from the mechanical analyses of samples collected, are not essentially different from many of the productive upland soils; but they are unproductive, and in extreme cases will not produce anything in a natural state except a stunted growth of small pines and knotty oak trees. At the best, they are stubborn and unproductive, and although many reasons have been assigned for their sterility, none seem altogether satisfactory. Professor Merril,[1] in speaking of the Chester County barrens, just across the State line in Pennsylvania, says that these soils are derived from the slow decomposition of peridotites, rocks rich in iron-magnesium silicates, but almost wholly lacking in lime, potash, or other desirable constituents. Hence the soils derived from such rocks are naturally devoid of nutrient matter and can only support a scanty growth of grass and stunted shrubs. The main reason which may be assigned for their unproductiveness is the large percentage of magnesia which they contain, and their slight depth. The analyses of these soils show that they contain very minute quantities of lime and phosphoric acid. Where sufficiently deep to retain moisture for the growing plants, if supplied with manures they are found to be as productive as many soils which have never been called barren.

The following table gives the mechanical analyses of a typical soil and subsoil of the Conowingo barrens:

Mechanical analyses of Conowingo barrens.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4244	Mount Pleasant, one-half mile W.	Yellow loam, 0 to 12 inches.	3.18	1.10	1.64	1.66	8.10	16.24	53.06	15.52
4245	Subsoil of 4244........	Brown loam, 12 to 40 inches.	4.51	1.10	1.72	1.22	6.34	15.34	55.80	14.29

[1] Rocks, Rock-weathering, and Soils, 1897.

CONOWINGO CLAY.

There are four small areas of Conowingo clay in the northwestern part of Cecil County. These areas partially surround the Conowingo barrens, and also come in contact with the Cecil clay formation. The surface of the country occupied by these small areas is as rough and broken as in the formation just described, but it consists of large, rounded hills or long, gentle slopes. The greater part of the formation is situated from 200 to 540 feet above sea level. The highest point in Cecil County is found in the area of Conowingo clay, just southwest of Silverspring.

These soils are derived from the decomposition of greenish, serpentine rock, and are usually of sufficient depth to make good lands. A considerable part of the areas is cleared and cultivated the same as are the other productive soils of the uplands. The soils are brownish and yellowish loams, which are underlaid by yellow and red stiff clay loams to a depth of 3 or 4 feet. There is a small amount of broken rock and quartz on the surface, but the percentage is not greater than the average of the upland soils. They are strong soils, which hold moisture and fertilizers well. In many respects they resemble the Cecil clay, but the subsoils of these clays are of a peculiar shade of red, and the soils are not as productive as the Cecil clay. They will produce good crops of tomatoes and corn. Wheat, for some reason, will not yield as well as on the Cecil clay or Cecil loams, but it is rotated with the other crops. The forests consist of a heavy growth of hard wood.

The following table gives the mechanical analyses of the soil and subsoil of the Conowingo clay:

Mechanical analyses of Conowingo clay.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
4248	East of Pilot	Red-brown loam, 0 to 8 inches.	3.92	2.16	3.64	2.52	6.17	9.33	50.40	22.15
4249	Subsoil of 4248	Red clay loam, 8 to 48 inches.	6.67	2.42	3.88	2.85	5.90	11.05	30.69	36.91

SASSAFRAS LOAM.

The largest areas of Sassafras loam are found on the Sassafras Neck, Middle Neck, and the old historic Bohemia Manor, but there are also areas of considerable importance north and northeast of Elkton and east of Perryville. This formation, unlike any of the preceding, lies

entirely within the borders of the Coastal Plain country. It occurs in the southern part of the county as broad, gently rolling terraces, from 40 to 80 feet above mean tide level. In the central portion of the county the formation occurs as sloping terraces, which rise from 40 to 240 feet above tide level. In many places these terraces are level, with almost no difference in elevation for miles. This is especially the case in the neighborhood of Warwick, on Sassafras Neck. Here the country seems to present the perfectly level condition of the old sea floor as it must have appeared when it first emerged from the sea.

The drainage has become established to some extent, and, although there are some small undrained places, the greater part of the larger areas is well drained. Examples of poor drainage on the river necks covered by this formation are shown in the small, circular, pond-like areas, seldom of more than a few acres in extent. In dry weather these places dry up, but during seasons of considerable rainfall they usually contain some water.

The streams of this formation are usually short and carry a small volume of water, for they drain but small areas. In their lower courses they have a width altogether disproportionate to their drainage basins. This is supposed to be due to the fact that this section of Maryland is gradually sinking, so that the lower parts of these small streams may be said to be drowned, and consist of broad expanses of water which rise and fall each day with the incoming and outgoing tides.

The soils of this formation are derived from the weathering of the beds of loam, which are characteristic of certain portions of the Columbia formation. These deposits were laid down in comparatively quiet waters, and since their deposition have undergone but little change. The uniformity of the soils is evidence of the widely extended conditions of deposition over the sea floor. The soils consist of from 8 to 10 inches of light-yellow loam. It is mellow and light, free from stone and gravel, and therefore easy to cultivate, and is underlaid by yellow loam usually heavier in texture than the soil. The subsoils often have a depth of several feet. They are always at least 36 inches in depth, and they generally grade into beds of gravel and sand.

These soils are fertile and productive, and can be brought to a high state of cultivation. Generally, they are naturally well drained, but in some of the more level portions of the uplands they are swampy, and would be much benefited by thorough underdrainage. The country around Warwick, on Sassafras Neck, is inclined to be swampy, especially in wet seasons. Although these soils are uniform, and can be easily recognized, there are some localities where they are slightly lighter in texture, but their generally loamy, mellow nature is noticed wherever the formation occurs. These soils have for a long time been cultivated, and on certain portions of the formation many pros-

perous farms are located. In other portions the farms are largely in the hands of tenants, and although the soils are productive, the general condition of these places is somewhat run down and neglected.

In good years from 20 to 25 bushels of wheat per acre can be raised, but in poorer years 12 to 15 bushels are considered an average crop. Corn will produce from 40 to 60 bushels per acre, about the same yield as the Cecil loam. Oats will yield from 40 to 50 bushels per acre, and good crops of clover and timothy hay are also raised. Tomatoes are grown in small quantities with success on these soils.

The following table gives the mechanical analyses of the soils and subsoils:

Mechanical analyses of Sassafras loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4040	Cecilton, 3 miles SE	0 to 10 inches	4.13	0.77	1.61	2.07	4.07	17.73	63.43	7.10
4034	Bohemia Bridge, 1½ miles S.	0 to 12 inches	3.42	4.44	7.97	4.12	4.65	16.08	50.57	8.68
4038	Concord, one-half mile N.	0 to 10 inches	2.70	1.13	2.38	1.75	7.53	21.19	52.77	10.25
4041	Subsoil of 4040	10 to 30 inches	2.78	......	1.04	1.40	2.55	19.19	60.35	12.22
4035	Subsoil of 4034	12 to 30 inches	2.57	7.97	13.97	5.37	5.31	12.81	38.83	13.33
4039	Subsoil of 4038	10 to 30 inches	2.70	Tr.	2.17	1.30	4.72	17.11	55.22	15.80

NORFOLK SAND.

The largest continuous area of Norfolk sand is just south of Elkton, the county seat, and north of Chesapeake City. In addition to this large area the formation occurs as a fringe, varying in width from one-fourth of a mile to slightly more than 2 miles, bordering all of the deeply indented river necks of the southeastern part of Cecil County. (See fig. 11.) The larger areas occur as a rolling upland, from 20 to 80 feet above sea level, but where it forms a border around the river necks it extends from the shore line to an elevation of 140 feet. Generally, it consists of sloping terraces, but there may be well-marked rises from a lower to a higher terrace. There are no undrained areas in this formation, but it often surrounds large marshy places along the broad river and bay shore lines.

The Norfolk sand is derived from sandy and gravelly beds of the Columbia. These materials were deposited in comparatively shallow waters by changing currents, which were strong enough to carry coarse grades of sand and occasional beds of gravel. These soils consist of reddish and brown sands, from 8 to 12 inches in depth, overlying subsoils which consist of sands of a reddish or yellow color.

The subsoils contain much less organic matter than the soils, and the sand is generally more compact. Often there may be a trace of well-rounded quartz gravel on the surface, varying from 1 to 6 inches in diameter. On the steeper slopes around the outer margin of the upland of the broad terraces there is often a belt or zone where large rounded gravel and bowlders come to the surface, but outcroppings of this nature are seldom noticed on the more gentle slopes. The occurrence of gravel and bowlders is more prominent on the steeper slopes around the margin of Sassafras Neck. Gravel beds underlie the Norfolk sand soils, and thus insure their perfect drainage.

These soils have never been brought to a high state of cultivation, and the region covered by them is not very prosperous. They sup-

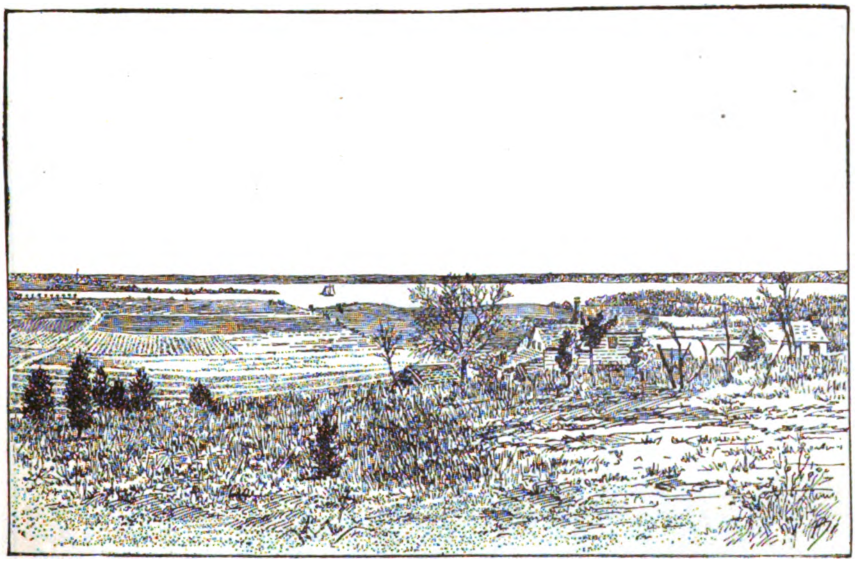

FIG. 11.—Low terraces of Norfolk sand along Elk and Bohemia rivers (drawn from illustration in Vol. I, Maryland State Weather Service).

port a native forest growth, consisting principally of oaks and chestnuts. The same crops are cultivated on these soils which are grown on the heavier and more productive soils, and the comparison of the respective yields of the two classes is not favorable to the sandy soils. On account of their light, sandy nature, they are not adapted to raising wheat and grass, and these crops are grown with almost invariably poor results. Corn does better, but the yields do not compare favorably with the better class of lands in this part of the county. If crops more adapted to a light, porous soil were grown, much better results could be expected. Almost any truck crop or small fruit would succeed. Growing peaches for market would doubtless prove much more profitable than the raising of wheat and corn with the present low yields and low value. The lands between Elkton and

Chesapeake City are in a much poorer condition than might be expected, when the capabilities of these soils for growing special crops are considered.

SUSQUEHANNA GRAVEL.

The Susquehanna gravel also ranks as one of the large soil formations of Cecil County, occupying large areas in the northeast district and the greater part of Elkneck. In the central portion the formation occurs as a series of large hills, situated along the junction of the Coastal Plain formations with the rolling uplands of the Piedmont Plateau. Elkneck, or more properly speaking, that portion occupied by the Susquehanna gravel, consists of a continuous chain of steep, rounded gravel hills. The entire surface of the formation is quite

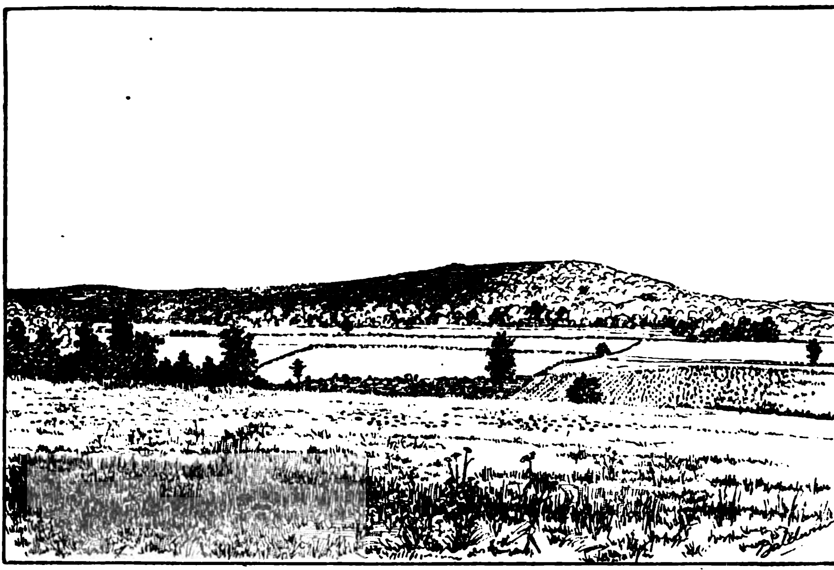

FIG. 12.—Characteristic topography in Susquehanna gravel area.

rough and hilly, with here and there a long slope, which breaks the monotony of steep hills and narrow valleys. (See fig. 12.) On Elkneck the hills rise from 200 to 300 feet above the bay. In the central portion of the county the elevations are somewhat greater, some of the hills rising considerably over 400 feet above mean tide level.

The soils are derived from the gravel beds of several different geologic formations, the principal ones being the late Pliocene and early Pleistocene. These deposits were laid down by swift currents of water during recent geological times and have undergone little subsequent alteration or change. The soil varies somewhat in its composition, but always contains a high percentage of large, well-rounded, quartz gravel, which ranges from one-half to several inches in diameter. To a depth of 8 inches the soil is a gravel loam, beneath which

the gravel content increases to such a great extent that it is almost impossible to penetrate farther with a soil auger. Often the underlying gravel beds are very compact and partially cemented together by a red ferruginous cement. In many places on Elkneck the surface is thickly strewn with great blocks or bowlders of these ferruginous conglomerates, many of which are several feet in length. In the central part of the county the gravels may be deeply stained with iron rust, while in adjoining localities they may be bleached perfectly white. The thickness of these gravel beds varies considerably in different parts of the formation, frequently exceeding 10 feet in depth. Along the northern border of the formation the gravels are mere superficial deposits scattered over the residual soils of the Piedmont Plateau. These gravels were probably once much thicker, but erosion since their deposition has carried them away until now they are thickly scattered over the surface of the rounded hills and slopes of the upland.

The texture of typical samples of the Susquehanna gravel soils can be seen in the following table:

Mechanical analyses of Susquehanna gravel.

[Fine earth.]

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
4242	Woodlawn, 1 mile W.	Gravelly loam, 0 to 14 inches.	5.16	7.58	11.58	15.99	9.70	11.99	30.32	7.37
4241	Principio, 3 miles S.	Gravelly loam, 10 to 26 inches.	2.53	5.07	8.88	15.68	24.28	11.89	14.68	16.92
4243	Subsoil of 4242	Red gravelly loam, 14 to 36 inches.	4.31	4.22	4.32	8.63	8.12	11.85	41.95	17.27

The productiveness of this soil formation also varies greatly, depending on the materials mixed with gravel. On Elkneck and on the larger hills in the northeast district the gravel is mixed with coarse sands and is well-nigh worthless for farming purposes. These lands have always been held in low esteem, and but few if any attempts have been made to cultivate them. They are covered with a thick but small growth of oaks and chestnuts. In many places a small part of the timber is burned for charcoal and, when the iron-ore mines were in operation many years ago, the charcoal industry was of considerable importance. These gravels compact into excellent roads. One may ride for miles in the poorer sections of this formation without seeing any attempt at cultivation, and the general appearance of the country is desolate in the extreme.

In the northern part of the area, along its border, where the covering of the gravels is not so deep and where the underlying materials form a combination more favorable for the agriculturist the country assumes a more prosperous aspect and many well-improved farms are to be seen within the limits of this formation. Here it is possible for the plow to mix with the gravel the residual products of the underlying granites and gneisses, and, although still containing a large amount of gravel, the soil is stronger and more productive. A larger timber growth is noticed, and crops that compare favorably with the better class of soils of the county are harvested each year. It frequently happens, even in the poorest, hilliest regions of this formation, that on the long slopes the gravel may overlie a clay which, when mixed with the soil, is fairly productive. There is no doubt that these soils will produce well by applying manure to them, but not such fine crops will be secured as are grown on heavier soils. Crops of wheat yielding 10 bushels per acre are sometimes obtained on fields where the soils seem almost worthless gravel. In some places good yields of corn are obtained, and tomatoes grow rapidly and abundantly, being cultivated extensively in some parts of the area.

ELKTON CLAY.

There are several well-defined areas of this formation along the eastern part of the central portion of the county, the principal ones being located near Elkton and southwest of Chesapeake City. This formation often occurs as well-marked terraces on portions of some of the broad rolling river necks of the lower part of the county. These terraces vary in elevation above tide level from 20 to 180 feet. Elkton is situated along the southern margin of one of the broad, flat terraces which only rises a few feet above mean tide level. Often these areas are low and poorly drained, and they are therefore wet and swampy much of the year.

The soil consists of from 8 to 10 inches of soft loam, which is often grayish in color, sometimes whitish, but the most common colors are brown and yellow. The soil is not unlike that of the Sassafras loam. The subsoil has a depth of 16 inches, consisting of a yellow light clay loam, which is underlaid by a mottled clay loam or clay to a depth of at least 36 inches. This subsoil is of various colors—drab, yellow, red, and pink all mixed together, best described by the term mottled clay. As this clay is very compact the natural drainage of the soil through such material is by no means good. Where this soil occupies a place where the natural conditions are conducive to good drainage the soils are productive and yield good crops of wheat, corn, and grass, as well as oats, potatoes, and tomatoes, but where the formation occupies areas with little opportunity for natural drainage it makes an undesirable soil for general farming purposes. These soils are apt to be cold and wet and late in the spring on account of the compact

nature of the clay subsoils. They bake hard in dry seasons, and it is difficult to keep them in good condition at any period of the growing season. The wet, poorly-drained land on the north of Grays Hill is just such an area. About Elkton and on many other occurrences of this formation are fine farm lands, where good crops are harvested as a general rule. Many dairy farms are situated on these soils. In some few areas a slight trace of white quartz gravel is scattered on the surface, but this is only in exceptional occurrences. Southwest of Chesapeake City are some areas with a thick, heavy growth of oak and pine, but this does not represent the original timber.

SUSQUEHANNA CLAY.

Susquehanna clay, with the possible exception of the Conowingo barrens, is probably the most unproductive soil formation found in Cecil County. The principal area is several miles in extent in the neighborhood of Charlestown, at the head of Northeast River. There are other areas surrounding some of the hills on Elkneck and a small, typical area surrounds the western part of Grays Hill, east of Elkton. The surface generally consists of eroded, even terraces or long deep slopes around the larger hills of Susquehanna gravel. The formation is often found at an elevation of a few feet, but it seldom exceeds 200 feet.

This formation is composed of some of the older Coastal Plain series of deposits, which are capped by a slight covering of late Pliocene and early Pleistocene gravels. The soils of this formation are derived mainly from the series of stiff, impervious clays, for many years grouped under the head of the Potomac formation, but in the last few years this group has been considerably subdivided by geologists. Although the stiff clays are capped by a slight covering of gravelly loam, they are sufficiently near the surface to give character to the soils. The capping on the more level portions consists of from 6 to 10 inches of loose gravel loam. On the slopes and on places where washing is more pronounced the covering of gravel may be removed and the refractory clays are exposed at the surface. Whether or not the gravel is present, the soil of the Susquehanna clay is distinctive and the condition of the country extremely desolate.

Few attempts have been made at cultivating these soils, and these have generally been unsuccessful. The soil is usually considered too worthless to pay the cost of clearing, and the few attempts made at cultivation have proved decidedly discouraging to the farmer. In some localities small fields of corn and wheat were observed, but the yields are small and the stubborn clays difficult to get in condition. Wherever this clay is without a gravel covering it is so stiff that it is plowed with the greatest difficulty. Generally, clay soils are considered productive, but these prove a notable exception. They are almost

impervious to water, and it has been remarked[1] that so slowly does the water move through them that the growing plant will suffer for want of moisture in the midst of plenty.

The timber growth of these soils is characteristic and distinct from that of the Susquehanna gravel, with which this formation nearly always comes in contact. Pine and oak constitute the growth, and the line of demarcation between the Susquehanna gravel and the present formation is well shown by the presence of the pine on the Susquehanna clay. The growth is thick, forming pine thickets rather than heavy forests. The Pennsylvania and the Baltimore and Ohio railroads pass through areas of this formation, the poverty of which is always remarked, much to the detriment of this section of Maryland, as the impoverished condition of this formation is wrongly supposed to be indicative of a much larger section of the State.

The texture of a number of samples of the Susquehanna clay formation is given in the following table:

Mechanical analyses of Susquehanna clay.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4025	Plum Point, 1¾ miles NW.	Stiff red clay, 0 to 8 inches.	4.15	Tr.	0.64	0.27	2.77	12.86	36.87	42.26
4028	Leslie	Stiff yellow clay, 4 to 36 inches.	4.33	0.78	1.84	1.76	5.66	11.43	39.61	34.95
4023	Plum Point, 1¾ miles NW.	Stiff red clay (road cut).	4.28	......	......	Tr.	2.12	17.42	40.13	36.20
4026	Subsoil of 4025	Red clay, 8 to 36 inches.	4.78	......	.75	.31	2.00	9.20	31.27	51.39

[1] Maryland Experiment Station, Bul. 21.

SOIL SURVEY OF ST. MARY COUNTY, MD.

By JAY A. BONSTEEL.

GEOGRAPHY.

St. Mary County comprises about 360 square miles of territory, bounded on the northeast by the Patuxent River, on the east by Chesapeake Bay, on the south and southwest by the Potomac River, and on the west by Wicomico River and Budds Creek. All of these waters except Budds Creek are either salt or brackish, and in the Patuxent and Potomac rivers the tides rise to points far beyond the boundaries of the county. On the north, for a distance of about 25 miles, the boundary separating St. Mary from Charles County is an irregular land line, except along the northeastern portion, where Indian Creek forms the boundary.

St. Margaret, Bullock, St. Catherine, Blackistone, Heron, and St. George islands lie within the limits of the county, since the jurisdiction of Maryland extends to the water's edge along the Virginia shore of the Potomac instead of running only to the middle of the river. The longest streams of St. Mary County, especially in the southern portion, are tributary to the Potomac River and to indenting bays. The chief streams are Chaptico Creek, St. Clements Creek, McIntosh Run, and St. Mary River. None of these streams are navigable.

The southern coast of the county is indented by numerous embayments. Notable among these are Chaptico Bay, St. Clement Bay, Breton Bay, and the estuary and mouth of St. Mary River. The county lies between the parallels of 38° and of 38° 30′ north latitude and between the meridians of 76° 20′ and 76° 55′ west from Greenwich. It is irregular in outline, constituting a large peninsula stretching southeastward between the waters named. The county is the most southern of the Maryland counties occupying the western shore of Chesapeake Bay.

HISTORY.

St. Mary County was the scene of the earliest permanent colonization within the present limits of the State of Maryland, with the exception of a small settlement on Kent Island. In the year 1634 Lord Baltimore's first colonists were sent out, and after touching at Jamestown, Va., they sailed up the Chesapeake Bay to the mouth of

the Potomac River. Proceeding up this stream, they landed on St. Clements (now Blackistone) Island, where Governor Calvert took formal possession of Lord Baltimore's grant. This, the first authorized settlement in the State of Maryland, was made in what is now

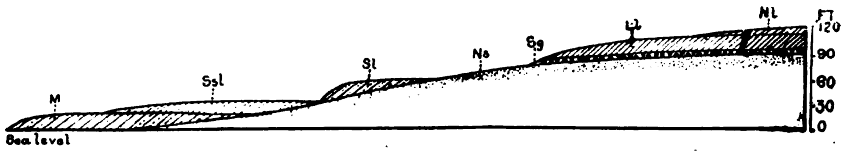

FIG. 13.—Diagrammatic section from upland to tide level, showing outcropping soil formations and terraces: *M*, Meadows; *Ssl*, Sassafras sandy loam; *Sl*, Sassafras loam; *Ns*, Norfolk sand; *Sg*, Susquehanna gravel; *Ll*, Leonardtown loam; *Nl*, Norfolk loam.

St. Mary County. St. Mary City, formerly an Indian village, was the first permanent settlement made, and it was the capital of this colony from the time of its settlement until October, 1694.

PHYSICAL GEOGRAPHY AND GEOLOGY.

St. Mary County lies wholly within the Coastal Plain area of Maryland. It consists of an interior upland division, rising from 90 to 200

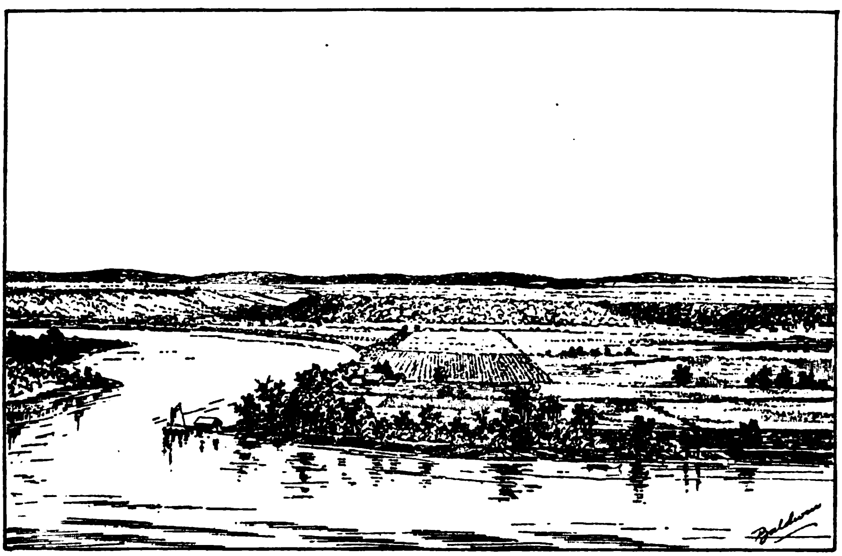

FIG. 14.—Meadow in foreground terrace of Leonardtown loam, with Norfolk loam and Windsor sand in background.

feet above sea level, and of a low-lying foreland border varying from 15 to 45 feet above sea level. The county is very much indented by large estuaries or bays, particularly on the Potomac side. The

streams of any length flow into the Potomac drainage system, while only steep-walled streams of short length are tributary to the Patuxent.

As in Calvert County, the basal skeleton of St. Mary County is built up of unconsolidated strata, only Neocene formations being found in St. Mary. The materials composing these strata are the same as in Calvert County, even in respect to the marl beds. In the same way the later Pleistocene deposits are far more directly concerned in the formation of soil types than are the older strata, and the correlation of soil types with geological formations given in considerable detail for Calvert County also applies to St. Mary. An ideal section showing the arrangement of soils is illustrated in fig. 13.

The chief geological difference between the two counties lies in the fact that in St. Mary the Eocene strata do not reach the surface, while in Calvert they do, and the Nomini formation is much more widely developed in southern St. Mary than in Calvert. The shell marls are the only ones present in large quantities in St. Mary County. Fig. 14 gives an idea of the arrangement and relative position of the principal types of soils.

SOILS.

The soils have approximately the following areas:

Areas of the different soils.

Soils.	Acres.	Per cent.	Soils.	Acres.	Per cent.
Leonardtown loam	95,500	41	Norfolk loam	8,500	4
Meadow	54,200	23	Susquehanna gravel	7,350	3
Norfolk sand	27,500	12	Windsor sand	3,450	2
Sassafras sandy loam	17,500	7	Swamp	2,200	1
Sassafras loam	16,200	7			

NORFOLK LOAM.

Norfolk loam extends as a long narrow strip along the highest portion of the divide between the Patuxent River drainage and that of the Potomac River. It also occupies small, irregular, scattered areas covering the flat plateau of the northern portion of the county.

Along the Three Notch Road, which follows the main divide of the county, the area occupied by the Norfolk loam presents a slightly rolling upland, varying from 120 to 165 feet in elevation. The highest elevations and the intervening hollows are included in the area covered by this soil.

The soil itself consists of a fine sandy to silty loam, reaching to an average depth of about 1 foot. When dry it is powdery and loose,

resembling corn meal in texture, distinctly lacking the smooth, clayey feeling of the finer-grained Leonardtown loam. When wet it packs to a firm surface, which cakes slightly through sun drying. In plowed fields this soil, though distinctly sandy, may clod into large-sized lumps. The subsoil is a reddish yellow sandy loam, finer in texture than the surface soil. It extends to a depth of about 30 inches and is almost universally underlaid by a coarse red sand mixed with fine gravel, having an indefinite depth.

The soil supports a natural growth of pitch pine, white oak and black oak, and chestnut, this latter tree occurring more frequently on this soil than on any other type represented in the county. The areas of Norfolk loam occurring in the northern portion of St. Mary County, particularly in the vicinity of St. Joseph's Church, constitute what is locally recognized as one of the most desirable tobacco soils in the county. The average yield per acre is about 1,300 pounds, and the average price about 6 cents per pound. Wheat, corn, and clover are also raised on this soil in regular rotation with the staple tobacco crop. The yield of these crops on the Norfolk loam compares favorably with the average yield of the same crops over the entire area of the county.

The following analyses show the texture of the soil and subsoil of the Norfolk loam:

Mechanical analyses of Norfolk loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5110	2½ miles W. of Sotterly.	Yellow sandy loam, 0 to 10 inches.	2.09	2.64	10.04	12.43	27.40	12.45	23.50	9.70
5112	1 mile E. of Newmarket.	Yellow sandy loam, 0 to 14 inches.	1.61	Tr.	.53	2.11	36.67	18.66	31.08	9.24
5111	Subsoil of 5110	Medium red sand, 10 to 40 inches.	2.10	2.61	12.46	14.35	31.94	7.78	13.89	14.91
5113	Subsoil of 5112	Red sandy loam, 14 to 30 inches.	2.03	0.00	Tr.	2.38	35.11	19.44	17.32	23.63

LEONARDTOWN LOAM.

The most extensive soil type in St. Mary County is the so-called white-oak or kettle-bottom soil of the upland. It extends from the vicinity of Ridge post office to the extreme northern limit of the county. The surface is slightly rolling or gently sloping, and the

broad, flat divides between the minor streams are covered by this soil. As the soil bears quite a variety of local names, it has seemed best to supplant them all by the name Leonardtown loam.

The extensive forests of white oak and pitch pine occurring over the upland region are found largely on this type of soil. Where small irregular depressions without any outlet are found the sweet gum also flourishes. Where the Leonardtown loam is exposed on slopes to the washing action of rains, scalds or washes frequently form and they rapidly encroach upon the arable land. A permanent sod is the only sure cure for these scars, though brush dams cause a temporary delay in the progress of erosion.

The cultivated areas of Leonardtown loam vary considerably in the

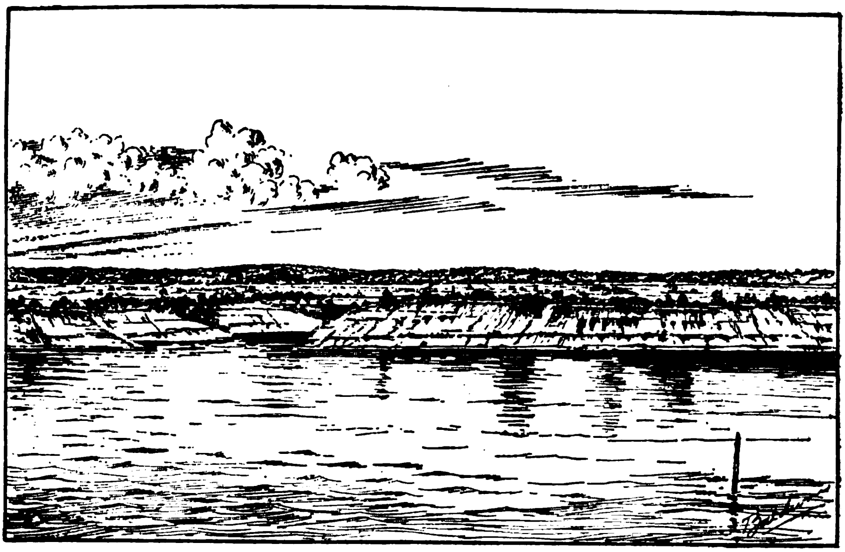

FIG. 15.—Leonardtown loam, with Norfolk loam and Windsor sand in background.

amounts of the various crops produced. Wheat, corn, and grass are best suited to this soil, while tobacco is better adapted to lighter, sandier soils. This soil type forms the nearest approach to the heavy clays of limestone regions that is found in the Coastal Plain of Maryland. A treatment similar to that employed on the limestone soils should increase the productivity of the Leonardtown loam.

The soil consists of a silty yellow loam, fine and powdery when dry, but puddling to a plastic clay-like mass when thoroughly wet. On redrying, this mass usually bakes to a hard, firm surface, or if stirred before being sufficiently dried, it clods up into hard lumps. The subsoil consists of a brittle mass of clay lenses, lumps, and fragments separated from each other by seams and pockets of medium to fine

sand. The subsoil, if evenly mixed, would form a somewhat sandy loam, but its peculiar structure causes it to act like a dense clay in its behavior toward the water circulation. The lenses of clay are slightly flattened and their edges overlap somewhat like the shingles on a roof. Consequently, water in its passage through the subsoil, follows a roundabout course along the sand-coated seams. Its progress downward is thus much delayed, and the subsoil is as impervious and as retentive of moisture as a heavy clay soil. The peculiar structure also gives rise to the brittleness noticed on plowing.

The bright-yellow color of the soil indicates a lack of organic matter. This can be corrected by plowing under green crops and by the application of stable manures. The tendency toward puddling and baking

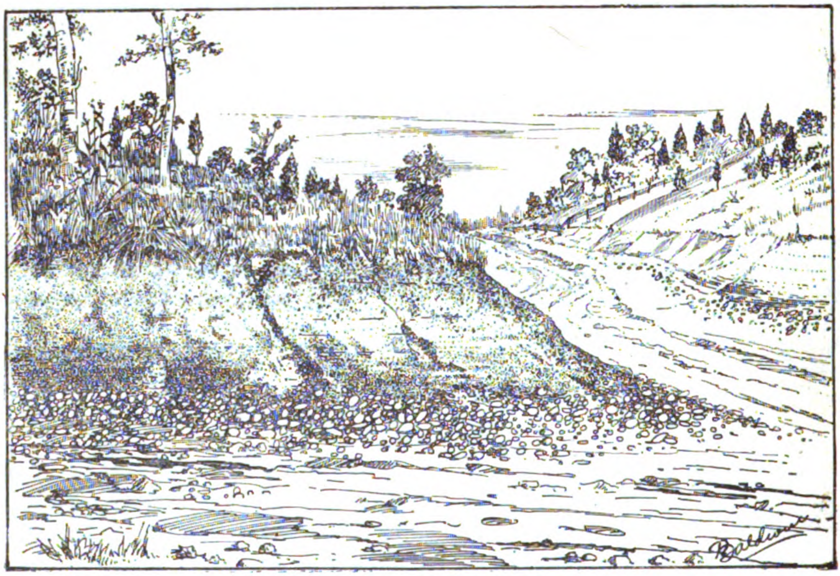

FIG. 16.—Leonardtown loam, with narrow band of Susquehanna gravel overlying Norfolk sand.

may be corrected by the application of lime. Figs. 15 and 16 show something of the general character and position of the Leonardtown loam.

As has been indicated in the comparison of this soil with the residual soils of limestone areas, the Leonardtown loam is a type best adapted to the production of grass and grain crops, and certain portions of the area found in St. Mary County are at present producing good hay and grain crops. The gradual introduction of live stock should largely increase the producing capacity of this soil, since the crops best suited to the soil can be fed directly to cattle. The saving in the fertilizer bill in this connection is an important item in farm economics.

The following analyses show the texture of the Leonardtown loam soil and subsoil:

Mechanical analyses of Leonardtown loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5114	3 miles W. of Leonardtown.	Yellow silty loam, 0 to 12 inches.	2.41	Tr.	.89	1.33	5.09	11.37	58.26	19.90
5116	1 mile S. of Loveville.	Yellow silty loam, 0 to 12 inches.	2.24	0.00	Tr.	3.16	17.62	18.76	47.75	9.69
5118	4½ miles E. of Leonardtown.	Yellow silty loam, 0 to 10 inches.	2.97	Tr.	1.38	1.91	3.87	21.90	58.46	10.06
5127	2 miles SW. of Newmarket.	Yellow silty loam, 0 to 9 inches.	2.11	Tr.	3.05	4.19	9.79	16.54	55.70	8.03
5115	Subsoil of 5114	Yellow loam, 12 to 34 inches.	1.96	Tr.	.76	1.19	5.26	13.92	55.02	21.94
5117	Subsoil of 5116	Yellow loam, 12 to 30 inches.	3.07	0.00	Tr.	3.28	9.08	11.96	49.24	22.59
5119	Subsoil of 5118	Yellow loam, 10 to 30 inches.	2.44	.67	1.24	1.83	4.63	15.46	53.39	20.37
5128	Subsoil of 5127	Yellow loam, 9 to 30 inches.	1.56	2.22	4.78	8.49	15.97	10.77	36.42	19.20

SUSQUEHANNA GRAVEL.

The layer of gravel which almost uniformly underlies the upland soil types, particularly the Leonardtown loam, reaches the surface along all the more deeply cut stream valleys and along the slopes separating the upland from the low-lying foreland border. The gravel works down across the slopes wherever it reaches the surface, and forms long, narrow bands of a distinctly gravelly soil. While of no great importance either in area or in agricultural value, it forms a marked feature of the land surface. In some instances the component materials are coarse enough to form stony bands and patches along the slopes. In other cases the finer gravel accumulates sufficiently to form small areas of poor or almost useless soil. This is the case on some of the smaller hills of the northeastern part of the county, where broken fragments of iron crust mingle with the gravel and sands.

Grapes are cultivated to advantage on similar soils in other regions, and their adaptability to this soil should be tried on a small scale in St. Mary County. In general, it would be better to allow forest growths to occupy the larger, more intractable areas.

The proportion of gravel in some of these areas is as high as 50 per cent, and with so coarse a texture it becomes almost impossible to maintain a sufficient supply of moisture to mature any long-growing crop. This is especially the case where the gravel areas lie on steeply sloping surfaces.

WINDSOR SAND.

The Windsor sand areas are found only in the northern portion of St. Mary County. They are marked by a strong growth of pitch pine and by the gravelly and sandy texture of the soil. At present these areas are imperfectly tilled to tobacco and grain crops, or occupied by small land holdings devoted to producing garden crops for household consumption.

The soil consists of a coarse to medium sand, containing considerable gravel. It extends to about 10 inches in depth, and is underlaid by an even coarser sandy and gravelly subsoil, frequently containing iron crusts in sheets and in broken fragments.

The value and capabilities of this soil have not been recognized as yet in this region. Its coarseness of texture, while precluding the profitable cultivation of grain crops, adapts it especially to the culture of early truck crops and peaches. The latter crop when raised on the Windsor sand produces a superior quality of fruit both in color and taste, and the orchards found on this soil in other localities are long lived, healthy, and profitable.

The Windsor sand areas of St. Mary County are all located within easy hauling distance of the present railroad points, and special crops of early fruits, vegetables, and peaches could find an easy and profitable market in the cities on connecting lines.

The surface of the Windsor sand is generally level and is little subject to washing on account of the porosity of the soil. It is easily cultivated and easily improved, and should form a valuable type for the special crops already discussed.

The following mechanical analyses show the texture of typical samples of the soil and subsoil:

Mechanical analyses of Windsor sand.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5129	Newmarket	Coarse sand, 0 to 9 inches.	1.43	5.48	14.29	14.04	38.63	15.16	8.10	2.76
5130	Subsoil of 5129	Sand, gravel, and iron crust, 9 to 28 inches.	1.02	10.20	20.92	12.18	29.30	11.58	10.99	3.81

NORFOLK SAND.

The Norfolk sand illustrates the fact that a single soil type may arise from materials deposited at different geological periods. In St. Mary County, soil of this type is found along the sloping sides of

streams as an outcrop of some of the basal formations of the county; again it occurs along the lower courses of these streams as flat-topped terraces built up from the older material by river transportation; while small areas of it occur along the forelands as material carried still farther seaward. All these deposits present the same sandy nature and form the same general type of soil, but they vary greatly in geological age.

Along the shallow stream channels of the forest area of the county narrow borders of this sandy soil are frequent. In the northern part of the county the streams have also cut into the sandy layer, which is the original source of this material. The covering of other materials has been washed away and considerable areas of Norfolk sand are exposed. Wherever found, this soil is recognized as well adapted to the Maryland type of tobacco, and it shares with the Norfolk loam in the reputation of producing a good grade and a reasonable quantity of the crop.

The soil consists of a red or brown sandy loam, having a depth of about 9 inches. This is underlaid by an orange or red sand to a depth of 3 feet or more. The natural growth on this soil includes chestnut, oak, and laurel. The Norfolk sand is a typical early truck soil, and has been very successfully farmed in truck crops all along the Atlantic coast. It produces a quick growth and early maturity, and is therefore much better adapted to the trucking business than to the production of grain crops, which require a longer growing season. Peaches, pears, early potatoes, and the common garden vegetables should be raised much more extensively than at present upon this soil whenever transportation facilities permit of marketing. The wild fruits like the blackberry, which flourish so remarkably on this soil, should be replaced by the cultivated varieties of the same fruits.

The following table gives the results of mechanical analyses of this soil type:

Mechanical analyses of Norfolk sand.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5133	4 miles E. of Leonardtown.	Fine yellow sand, 0 to 14 inches.	1.44	Tr.	2.74	7.38	38.57	21.77	22.37	4.82
5135	1¼ miles SW. of Hillville.	Medium yellow sand, 0 to 10 inches.	1.36	1.64	8.74	13.60	34.69	18.76	15.89	4.87
5134	Subsoil of 5133....	Medium red sand, 14 to 36 inches.	1.72	Tr.	2.31	5.88	34.91	20.66	22.52	11.96
5136	Subsoil of 5135....	Red sand and gravel, 10 to 28 inches.	2.00	4.30	12.65	13.69	31.22	10.10	10.12	15.23

SASSAFRAS LOAM.

This soil type occurs in St. Mary County at an elevation of from 60 to 90 feet above tide in the form of flat-topped terraces. It is generally completely cleared and well cultivated. It forms the best corn producing soils of this and other areas and is well fitted for general farming purposes. It is formed from a mixture of sand and clay derived from much older strata and reworked and redeposited by stream action.

The soil consists of a slightly sandy yellow or brown loam, having a depth of from 8 to 12 inches. This is underlaid by a heavier yellow loam to a depth of nearly 3 feet. This subsoil forms a good storage reservoir to maintain a moisture supply during the growing season without retaining enough water to interfere with cultivation or plant growth. Wheat, corn, and the grasses do well on this soil, while a fair tobacco crop can be raised on it; but it approaches more nearly to an easily worked medium grade of soil for general farming purposes. Pears and other fruits, together with tomatoes, asparagus, and canning crops should be introduced to give a greater variety in crops with increased opportunities for profits.

The use of lime and of green manures and stable manures will benefit this soil, though not so essential as in the case of heavier types.

The following table gives the mechanical analyses of Sassafras loam:

Mechanical analyses of Sassafras loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5137	1¼ mile W. of Sotterly.	Yellow silty loam, 0 to 9 inches.	2.22	1.21	4.51	4.57	14.94	13.26	49.87	9.45
5139	1 mile S. of Great Mills.	Yellow silty loam, 0 to 9 inches.	2.48	1.02	3.12	4.53	13.35	13.14	49.68	12.80
5138	Subsoil of 5137	Yellow sandy loam, 9 to 30 inches.	1.87	.84	4.51	5.79	22.62	10.54	33.84	19.61
5140	Subsoil of 5139.	Heavy yellow loam, 9 to 30 inches.	2.17	Tr.	2.45	4.02	13.72	12.63	50.56	14.16

SASSAFRAS SANDY LOAM.

Sassafras sandy loam occupies the low-lying forelands along the Patuxent and Potomac rivers and along the shores of the numerous estuaries and creeks tributary to those rivers. In fact, this soil formation extends as a discontinuous belt of choice farm land almost entirely encircling the county.

Lying between the more elevated uplands and the tide-water courses

of the chief rivers of the section, the Sassafras sandy loam slopes gently down from an elevation of about 35 feet nearly to water level, and presents a very nearly flat, though gently inclined, surface. Areas located on adjacent forelands are usually separated from each other by lower-lying strips of meadow lands located along the margins of the minor streams. To the rear of each area the surface usually rises with quite a steep slope to the more elevated plateau region.

The soil itself is probably a stream deposit, laid down at a time when the relative level of tide water in this region was at least 40 feet higher than at present, though the plateau portion of the county existed as dry land even then. The deposition of material derived from the upland by the streams of that day took place closely adjacent to the land area which existed there, and the coarser sands were deposited in those stream courses as noted elsewhere. The finer sand and silt, carried to a greater distance seaward because of the lightness of individual grains, were deposited in the region of tide water, with the coarser materials falling in shallower water near shore, as is the case with the present deposition in all regions. Thus, small sandbars and spits would be formed, and organic matter from the mainland and from the tidal flats usual along low shore lines would be commingled with the sand and silt of the bottoms of the estuaries. In such a manner the sandy loams of this foreland portion of the county most probably originated. As the relative elevation of land and sea changed, this new-formed soil became exposed, and encroaching land vegetation further aided in the preparation of the loam for agricultural purposes.

The soil is a dark-brown sandy loam, having an average depth of about 14 inches. The subsoil is heavier, in most instances consisting of a yellow or reddish-yellow sandy loam. At 30 inches depth the subsoil is normally succeeded by a reddish sand, though frequently this is wanting and a silty drab layer is found, which extends nearly or quite to tide level.

This soil is so well recognized as a desirable farming land that all original tree growth has been removed and the area is occupied by cultivated fields. Corn, wheat, and tobacco are raised on the Sassafras sandy loam, and the yield of each is somewhat higher than the average yield for the county. The average wheat crop will consist of about 15 bushels per acre; that of corn about 7 barrels, or 35 bushels; while the tobacco will grow to 1,600 pounds per acre, and will sell at 5 or 6 cents per pound. Of course, much larger crops are raised under favorable conditions, while unfavorable conditions of season or culture will correspondingly cause a decrease in yield.

In the Cedar Point area the production of green peas, tomatoes, and of sweet corn for canning purposes has been undertaken. The climatic and soil conditions are favorable to profitable production of these and other crops classed as truck or canning crops. Along the

Patuxent River, near Forrest Wharf, the culture of broom corn is being undertaken. The success of this attempt has not been learned.

Owing to the location of this soil along the shore near shipping points, as well as to its texture and general properties, it is well adapted to the raising of fruits, vegetables, and general truck crops which derive value from being placed on an early market. Its position also makes irrigation possible whenever the necessity for intensified cultivation shall manifest itself in this community.

The general character of the Sassafras sandy loam is indicated by the following mechanical analyses. It is noticeable that the subsoil in each case contains quite a large percentage more of clay than does the corresponding soil.

Mechanical analyses of Sassafras sandy loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*
5141	1¾ miles SE. of Stone Wharf.	Brown sandy loam, 0 to 16 inches.	2.55	Tr.	1.56	4.30	34.34	11.86	36.62	8.36
5144	2¼ miles S. of Leonardtown.	Brown sandy loam, 0 to 9 inches.	2.22	1.72	10.83	18.96	19.85	6.44	31.94	8.56
5147	1¾ miles NE. of Trap.	Brown sandy loam, 0 to 8 inches.	3.50	3.49	12.30	9.40	5.88	10.16	48.62	6.24
5149	¼ mile NE. of Cohouck Point.	Brown sandy loam, 0 to 12 inches.	2.93	4.87	17.49	11.83	11.08	9.82	30.59	11.55
5142	Subsoil of 5141....	Heavy brown loam, 16 to 34 inches.	1.66	.75	2.67	6.79	45.80	5.87	17.06	19.30
5145	Subsoil of 5144....	Red loam, 9 to 30 inches.	2.53	1.58	12.36	18.69	15.99	4.62	30.43	12.80
5148	Subsoil of 5147 ...	Yellow loam, 8 to 30 inches.	2.71	.99	7.03	6.15	3.76	11.20	51.80	16.48
5150	Subsoil of 5149....	Yellow sandy loam, 12 to 30 inches.	2.15	2.98	13.72	12.18	9.74	8.78	26.13	24.20

MEADOW.

The natural meadow lands of St. Mary County are usually flat or gently inclined areas occurring along stream courses or on the low flat forelands bordering the tide-water areas. The meadows are usually rather wet, and in many instances they differ from adjoining soil types in their relation to drainage rather than in their texture.

The natural forest growth over the meadows includes white oak, willow oak, sweetgum, and poplar, with frequently a matted undergrowth of shrubs and vines. The meadows furnish a rather coarse, rank grass for grazing and, owing to the mild climate of the region, cattle frequently find pasturage throughout the winter.

The large meadow areas of the forelands are frequently cultivated to the general farm crops, but in wet seasons they are difficult of tillage, and even in the most favorable seasons they produce only wheat

and grass to good advantage. They require extensive underdrainage; even open ditches are inadequate, for the soil is so dense and so near water level that surface drainage fails to lower the level of standing water sufficiently to aerate the soil thoroughly. The presence of excessive water in the soil thus tends to keep the ground cold and to delay seed germination and plant growth. Then, too, the organic acids tend to accumulate to excess, proving harmful to plant life and not fulfilling their function in the preparation of mineral matter to serve as plant food.

Proper underdrainage by lowering the water level will not only drain off surplus moisture, but will also permit a circulation of air, and thus aid in the natural improvement of the soil.

Many thousand acres of meadow land, now producing only a rank growth of grass or an uncertain crop of grain, can be made highly valuable by relatively cheap methods of underdrainage.

The soil of the meadow areas usually consists of 8 to 10 inches of gray silty loam underlaid by a subsoil of ash-gray clay loam. The soil mass is apt to be cohesive and clay-like when wet, but when subjected to the action of the frost and air it becomes powdery and crumbly, and is very much improved in texture. Drainage and liming should be resorted to in order to produce this result on a large scale.

The texture of this soil is shown by the following analyses:

Mechanical analyses of meadow.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5151	2 miles SE. of Briscoe Wharf.	Gray loam, 0 to 8 inches.	1.84	Tr.	0.88	0.83	3.76	23.35	59.59	9.58
5153	One-eighth mile W. of Short Point.	Brown silty loam, 0 to 7 inches.	2.32	1.41	3.33	4.12	6.46	15.41	58.54	8.32
5152	Subsoil of 5151	Drab clay, 8 to 30 inches.	2.89	0.00	Tr.	1.73	5.38	16.30	47.55	25.77
5154	Subsoil of 5153	Drab clay, 7 to 32 inches.	1.61	Tr.	2.01	2.61	7.11	11.40	60.11	14.74

SWAMP.

There are three types of swamp lands in St. Mary County—the tidal flats, which are wholly or partially submerged at each high tide; the fresh-water marshes, subject to frequent or constant inundation by streams; and the fresh-water bogs and swamps, due to incomplete head-water drainage or to natural or accidental artificial ponding back of stream waters.

The salt marsh at the head of Chaptico Bay and the flats at the head

of Breton Bay are the most extensive examples of the first class occurring in St. Mary County. Except at especially high spring tides these areas lie about 5 feet above the water level. They support a growth of marsh grass and reeds and possess a silty soil mixed with partially decayed vegetation. Some marsh hay is cut over these areas, and cattle and hogs find pasture where the surface is sufficiently firm to support their weight.

These marshy areas are formed by the deposition of fine sand, silt, and clay, brought down by streams and by the higher tides, together with the decaying remains of the vegetation which gains a foothold on the drier areas. These marshes are constantly growing in extent, and in many instances cattle are feeding on marshy meadows where small-sized boats floated in the early days of the colonization of the county. Farther from the mouths of the larger tributary streams, above the highest reach of the tide, the fresh-water marshes occur, as is the case along the Chaptico Creek, McIntosh Run, and many of the streams flowing into the Patuxent River. These marshes are similar to the salt marshes, except that they are only subject to irregularly occurring inundations below fresh water instead of periodic submersion by the tides.

The third class of swamps occupies positions at the heads of some of the main streams and along the upper courses of the majority of the smaller ones. The head waters of the St. Mary River drainage, found in the forest area around St. Andrew's Church, illustrate this condition markedly, though many other localities are very similar.

The surface in this forest area is slightly irregular and consists of Leonardtown loam and Norfolk sand. The hollows in both of these formations are swampy and grown up to gum trees. In wet seasons small ponds exist, which become dry, or nearly so, during the latter part of each summer. A slight clearing out of the natural drainage ways, connecting these ponds with stream courses, would destroy the ponds in most cases. Frequently the obstruction to drainage consists of a rank growth of vegetation, fallen tree trunks, and the accumulation of dead leaves and soil wash. In some few cases the grading up of highways or embankments constructed for proposed railways through the county has caused accidental artificial ponding of waters. These are of small extent and may be easily remedied by underdrainage.

CONDITIONS OF AGRICULTURE.

The condition of agriculture in any community depends upon four factors—soil, climate, transportation facilities, and the mental and physical energy of the population. The first two of these factors are natural, while the last two are to a great degree artificial. Usually it does not lie within the power of any community, however energetic, to modify the soils or the climate of a region to any marked extent. The great exception to this statement is in the arid States,

where irrigation has been introduced, transforming desert areas into fertile farms.

The actual conditions of the soil, the climate, and the transportation facilities of St. Mary County have been treated separately in other chapters, but a general resumé of the interrelationships of these factors and a slight reference to certain social and economic conditions prevailing in the county are necessary to a full appreciation of the present status of the county by its own inhabitants as well as by strangers.

The usual farm practice in St. Mary County is based on a rotation of crops, including tobacco, corn, wheat, and grass, or a season of fallowing. This rotation is observed on all soils in all parts of the county, though some individual farmers have modified it. Thus, in a great majority of cases, the fundamental factor of soil differences is neglected. The success of the rotation in the county has depended upon the highly accidental factors of the location of the farm and the energy of the farmer. Thus, the energetic man located on the proper soil for the tobacco crop will be highly successful, while his no less energetic neighbor located on the wrong soil may be unsuccessful, and the unenergetic man may absolutely fail.

The natural selection of farm lands dependent upon these conditions has led to the abandonment of large areas of the Leonardtown loam to forest occupation, for the soil is not adapted to the culture of the quality of tobacco which buyers expect from the county. On the other hand, the Norfolk loam is tilled over almost every acre of its extent, because it is adapted to the production of this chief crop.

In the same way natural selection has led to the extensive cultivation of the Sassafras sandy loam, and it is worthy of notice that the very first white settlers, as well as their Indian predecessors, located on this soil type chiefly because of its location near water transportation, but also probably in part because it is an excellent soil for general farming purposes. Contrasted with this soil are the large areas of meadow land still clothed with forest growth, though similarly located to the Sassafras sand loam. It is not entirely an accident that leads to these selections and to the introduction of new crops, such as peaches, on the Norfolk sand, or to the cultivation of canning crops and broom corn on Sassafras sandy loam. The climate of the region is suited to the crops, the soils are similar to those upon which the crops have been raised elsewhere, the facilities for transportation are in part equal to the necessities of the crops, while the energy required for their introduction is supplied by well-informed and progressive citizens of the county and of other regions.

A local and partly defined soil classification has been reached through this process of selection, though the areas suited to certain crops have not been located nor mapped over any part of the county until the present time. Nevertheless experience, often bought at a

dear price and confined to the few who have ventured their money and their time, has led to the partial classification already noted. It is hoped that the classification, the map, and the description of soil types contained in this report will facilitate further development along the lines of soil selection for special crops, will encourage the introduction of new crops, and will lead to a generalization of the experience gained by the few for the use of the many.

Closely associated with the adaptability of certain soil types to certain crops is the two-edged question of fertilizer, which is dependent for its answer upon the quality of soil to be fertilized and the kind of crop to be raised.

Probably every soil type in St. Mary County contains within 4 feet of its surface sufficient plant food to produce 100 crops of any kind which are raised or could be raised in the county. The necessity for fertilizer depends on the fact that much of this material is present in such chemical combinations and in such a physical state that some manipulation is required to release it and to bring it into solution in water so that the plant roots may absorb it. Certain chemicals found in commercial fertilizers and in stable manures tend to release this plant food and to form or supply soluble chemical compounds suited to the needs of the plants, while organic matter constitutes the best sponge for retaining the absolutely essential water supply in sandy soils, and acts equally well in loosening the too closely packed particles of heavier clay soils. The organic matter, through its decay, also furnishes actual plant foods and solvents for the preparation of other foods. The character of growth desired in special crops modifies the kind and amount of special fertilizers for those crops. For example, it is a generally accepted principle of tobacco culture in Maryland that liming land spoils the texture of the tobacco raised, causing it to spot and injuring the burning qualities for which it is so well known; therefore the use of lime on tobacco lands is precluded, though its use would be of undoubted advantage on all of the heavier soil types and upon most of the lighter types for other crops.

St. Mary County possesses large stores of carbonate of lime in the Neocene marl beds underlying all of the upland portion of the county and reaching the surface in nearly every cliff and stream cutting over the upper half of the region. This lime supply consists of the calcareous shells of marine shellfish which once lived upon the sea bottom when the ocean covered the county. The shells, buried in sand and elevated above water level, can be dug out by the wagonload and converted into excellent lime by sieving out the sand and burning the remaining shells, just as lime rock is burned to lime. The sifting would be unnecessary in the case of some of the deposits, since the small amount of sand present would be a benefit to the heavier types of land. The Leonardtown loam would benefit materially from such liming, except, of course, when tobacco is to be raised.

The plowing under of green crops, especially the leguminous plants

of the clover and cowpea varieties, furnishes another method of enrichment highly desirable on almost all the soil types of St. Mary County, and does not present the difficulties of liming, since this kind of fertilizer is of great benefit to the tobacco crop. These leguminous crops furnish a fair forage for cattle during a period of their growth, and if allowed to continue growing they produce a mass of organic matter for incorporation with the soil; and all the time, beneath the surface of the ground, certain minute bacteria, living on the roots, are taking nitrogen from the air and storing it in the soil, thus helping in the enrichment of the soil.

The ordinary practice of putting from 200 to 400 pounds of commercial fertilizer, costing from $18 to $40 per ton, upon the farms of St. Mary County has a double effect. It produces the crop, but it also enters a large item on the expense side of the farm account, and on some soils its continued use has the effect of burning out the soil, so that periods of fallowing become essential. For certain crops special fertilizers will always be necessary, and commercial fertilizers are to be commended highly, but in St. Mary County on all soils the use of stable manure and the plowing under of green crops are to be preferred, while on the soils least suited to tobacco the abandonment of that crop and the free use of lime in conjunction with organic matter have already become necessary, as is shown by the forest areas given over to nature's cultivation.

Many of the farm buildings of St. Mary County are of remote date. The farmhouses particularly are types of colonial structure, and the residence upon the farm at Sotterly is one built for the first governor of Maryland, while numerous other manor houses in the county are nearly as venerable. Even the less pretentious houses display the long sloping roofs, the gable windows, and the large end chimneys of the early colonial period. The atmosphere of antiquity, of romance, and of historic interest which surrounds these old residences and the equally venerable churches and farm properties gives a local color and a local pride to the county that can be shared only by other communities of equal age.

Outbuildings are not so essential in this climate as in regions of heavier snowfall, so the older farms are provided only with the tobacco barn, smokehouse, and corncrib of the plantation, the large stock and hay barns being almost totally unknown. Cattle can graze upon the meadow lands in all but exceptionally severe weather, and the side of some existing building or the shelter of woodland protects them during the coldest weather.

The fences are mostly built of rails and poles cut in the native forests, though some barbed and other patent wire fences have been introduced. The Virginia rail or worm fence is the most common type, while the mortised post, into which the ends of the rails are fitted, is also common.

No account of the condition of agriculture in St. Mary County would

be complete without a reference to the common draft vehicle and beast. Owing to the steepness of the grades and to the general difficulties attending land transportation, the ox cart is usually employed for heavy hauling. It is no uncommon thing toward the latter part of June to meet from one to twenty 4-ox or 6-ox teams attached to heavy 2-wheeled carts, upon which one or two tobacco hogsheads are being drawn to the wharves for shipment. Each hogshead constitutes an unwieldy mass of about 800 pounds of tightly packed tobacco, and the successful transportation of some of these loads down the steep slopes from the upland to the wharf, under the existing road conditions, is no small feat of engineering.

The field labor is largely performed by the numerous colored population of the county, some of whom labored as slaves on the same farms where they now work as free men. The majority of the workers, however, belong to a more recent generation.

The wants of these workmen are few (a cabin, a garden patch, and the most elementary house furnishings), the forest lands giving free grazing to the cow, the horse, and the pig of the landowner, the tenant, and the day laborer alike. Added to these conditions are a mild climate and usually a free supply of firewood, together with fish and oysters from near-by waters. As a result, a fair subsistence is easily obtained with a minimum of labor, especially as the colored laborers and their families are free partakers, through the generosity of their white employers, in the partly worn clothing and in the surplus provisions of their white employers. So while the actual cash wages will average only 50 or 75 cents per day, this sum will have a purchasing and sustaining power far in excess of the same amount in the more thickly settled and colder regions of the North. Men, women, and even children work in the fields together, particularly in caring for the tobacco crop, which requires a large amount of hand labor for setting the plants, hoeing, curing, and stripping.

Some of the colored men own their own farms, but the majority find a more congenial employment in the less exacting task of devoting most of their time to caring for the crops of others. The limited capital they can usually accumulate confines the colored farmers to what are generally considered as rather undesirable farm lands, most frequently Leonardtown loam, meadow, or Windsor sand areas. A change in crop production and farm practice will some day make these lands equal in value to others more desired at present.

There are no large towns in St. Mary County. Leonardtown, the county seat, is the largest, while Mechanicsville, at the terminus of the railroad, does a thriving business, and Charlotte Hall is the seat of a well-known school of the same name.

The tendency of the white population is toward the enjoyment of the seclusion of large estates, and frequently the manor house or farmhouse is reached only by a long avenue leading away to a distance of nearly a mile from the public highway. On the other hand, the col-

ored population segregates into little communities, where land may be obtained cheaply, and little villages of frame and log dwellings are dotted over the county.

TRANSPORTATION.

A single line of railway, connecting Mechanicsville with a main line at Brandywine, is the only rail communication in St. Mary County with the markets and cities of the State and with the country at large. This lack of railroad communication is partly relieved by the steamboat service on the Patuxent and Potomac rivers and on the larger streams. As two lines connecting with Baltimore and Washington control the water transportation, this can scarcely be said to equal the needs of the county. The boats run only at long intervals and at rather irregular times, and the trip to Baltimore or Washington consumes from sixteen to twenty-four hours, depending upon the volume of freight carried.

For this reason the crops produced in the county are placed at a disadvantage with relation to markets when compared with those of other regions, and the variety of crops that can be raised with profit is considerably restricted. This is particularly evident in the case of fruit and truck crops and of dairy products. The truck lands of St. Mary County are excellent, so far as soil and climate are concerned, but no one cares to enter into their cultivation to any extent so long as the cost and uncertainties of marketing remain as great as at present. Again, the Leonardtown loam, the Sassafras loam, and the meadow lands are well adapted to dairying and to stock raising, but the time distance from markets and the actual uncertainty of any communication during winter months retard or prevent introduction of stock.

The waterways for extensive steamboat communication exist, grades well adapted for railway construction are to be found, and the construction of the roadbed presents only the simple engineering problem of cut and fill, with no consolidated rock formations to require blasting. The soils, the climate, and the natural advantages of geographical location all favor the upbuilding of the county. It is likely that outside influences have combined with a well-defined conservatism in the native population to retard the development not only of this but of other localities in the general region.

The internal communications of the county consist of highly varied wagon roads. The main roads follow the main divides, while public and private roadways lead out along the secondary divides and down to the lowland farms and to the wharves. Bridges are scarce, and the small streams are crossed by fords. The tide-water indentations along the coast and the marshes at their headward extremities separate the farms along the forelands, and it is possible to go only from one foreland to another by considerable detour inland, usually including a steep ascent to the upland and an equally steep descent to the adjoining foreland. Foot passengers can usually find a small boat to

transfer them across such obstacles, and many of the farmers own sailboats, but regular ferries do not exist. There is no regular ferry or bridge across the Patuxent terminating in St. Mary County.

The wagon roads consist of sand, loam, or clay, as they happen to cross such materials, and the rain wash and the wear of travel have cut the roads down for long distances far below the surface of the country. In many places where the roadway has been washed to a state of impassability teams have driven around the gully and established a new highway, or an overturned tree is avoided similarly. One road district in particular has secured fairly good roads partly through the energy of its supervisor, partly because additional contributions above the annual tax have been given by residents of the district, and partly because the district contains better road materials than some others. The iron-stained gravels of the upland plateau should be used to a greater extent in surfacing its clay roads, but proper drainage and grading of most of the roads must precede any other work.

CLIMATE.

The following table of the climatic elements, compiled from the Maryland Weather Service, Vol. I, gives an indication of the average conditions to be expected in St. Mary County. No records for less than five years are considered, and consequently a few blanks remain in the table.

Average climatic conditions of St. Mary County.

CHARLOTTE HALL.

Month.	Normal monthly and annual temperature.	Normal maximum temperature.	Greatest departure above.	Greatest departure below.	Normal minimum temperature.	Greatest departure above.	Greatest departure below.	Mean daily range.	Highest recorded temperature.	Lowest recorded temperature.	Mean monthly and annual precipitation.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*In.*
January	35	43	+ 4	− 4	26	+ 4	− 4	17	66	− 1	2.8
February	35	44	+ 4	− 9	24	+ 3	−10	20	70	......	3.2
March	45	55	+ 5	− 8	34	+ 4	− 6	21	83	0	3.1
April	54	65	+ 5	- 3	43	+ 2	− 3	22	97	25	3.5
May	......	......	......	......	......	......	......	......	95	37	3.9
June	73	84	+ 3	− 5	62	+ 2	− 2	22	100	41	2.5
July	76	86	+ 3	− 2	66	+ 2	− 4	20	102	49	4.0
August	76	87	+ 3	− 4	65	+ 2	− 1	22	99	52	2.5
September	......	......	......	......	......	......	......	......	100	40	1.3
October	56	66	+ 2	− 2	46	+ 4	− 8	20	88	23	3.7
November	47	56	+ 8	− 4	38	+ 6	− 2	18	78	18	2.1
December	38	49	+ 1	- 3	29	+ 3	− 2	20	70	5	2.0
Annual	......	......	......	......	......	......	......	......	102	− 1	34.4

The last killing frosts in the spring have occurred at Charlotte Hall on April 21, 1897, and on April 6, 1898.

The first killing frosts in the fall have occurred at Charlotte Hall on November 13, 1897, with no record in 1898.

Average climatic conditions of St. Mary County—Continued.

CHERRYFIELDS.

Month.	Mean monthly and annual temperature.	Mean monthly and annual precipitation.	Month.	Mean monthly and annual temperature.	Mean monthly and annual precipitation.
	° *F.*	*Inches.*		° *F.*	*Inches.*
January	35	1.9	August	75	3.4
February	34	3.5	September	71	2.2
March	44	3.3	October	58	3.8
April	53	3.0	November	47	3.2
May	64	4.3	December	38	2.5
June	73	2.7	Annual	56	39.9
July	76	6.0			

ST. MARY.

January	35	....	August	....	....
February	37	....	September	71	....
March	43	....	October	58	....
April	55	....	November	47	....
May	62	....	December	39	....
June	73	....	Annual	....	....
July	76	....			

ST. INIGOES.

January	38	2.5	August	76	6.5
February	43	4.1	September	69	4.8
March	44	4.9	October	59	3.7
April	55	4.2	November	50	3.4
May	65	4.3	December	40	3.4
June	74	2.1	Annual	58	47.6
July	79	3.7			

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SOIL SURVEY OF CALVERT COUNTY, MD.

By JAY A. BONSTEEL and R. T. AVON BURKE.

GEOGRAPHY.

Calvert County comprises an area of 218 square miles of land surface lying between the Patuxent River and the Chesapeake Bay. It is the smallest county in Maryland. Its extreme length from northwest to southeast is slightly over 35 miles, and it varies in breadth from 9 miles in the northern part to about 5 miles in the southern part. The northern boundary of the county is formed by Lyons Creek and by 3½ miles of north-and-south land boundary, and about 5 miles of east-and-west land boundary, separating it from a prolongation of Anne Arundel County. On the west the Patuxent River separates Calvert County from St. Mary, Charles, and Prince George counties.

The entire area of the county is included between the parallels of 38° 20′ to 38° 45′ north latitude and the meridians of 76° 22′ to 76° 41′ west longitude. Its extreme elevation above sea level is less than 200 feet. Its long coast line and the numerous embayments along the Patuxent shore make the county easily accessible by water.

Prince Frederick is the county seat and Solomons its largest town. Agriculture and oyster fishery are the chief occupations of its inhabitants.

PHYSICAL GEOGRAPHY.

Calvert County extends as a long, narrow peninsula between two tidewater estuaries, and, while half of its area rises to 120 feet elevation or higher, the surface is uneven and much cut up by streams. This is due to the steep, short fall of the water courses and to the unconsolidated nature of the materials upon which the water acts. Hunting Creek, flowing into the Patuxent, and Fishing Creek, flowing into Chesapeake Bay, have nearly cut the county in two parts. Battel Creek and Parker Creek have almost accomplished the same dissection farther south, while St. Leonard Creek has its head waters within a half mile of Chesapeake Bay, though flowing into the Patuxent. Many smaller streams have trenched the surface deeply.

As a consequence of this active stream erosion, the greater part of the county consists of steep-sided, flat-topped hills and long, narrow necks of upland country. On the east this upland descends by a high cliff to the level of Chesapeake Bay throughout most of the

distance between Fishing Creek and Drumpoint. The streams flowing into Chesapeake Bay have cut deep notches in this cliff line and at some points, as at Dares Wharf, slight remnants of old terraces remain between the general upland level and the water's edge.

The western shore line is quite different from the eastern coast. The surviving portions of upland extend nearly to the Patuxent River as long, narrow divides with flat or rounded tops. The slope toward the river is usually very steep and rarely descends entirely to water level. Along the greater part of the Patuxent shore line a narrow, flat-topped foreland or terrace is found between the upland slope and the water. In the vicinity of Solomons Island and St. Leonard Creek this foreland has a breadth of about 2 miles, and its surface lies at an elevation of between 20 and 40 feet above tide level. Between St. Leonard Creek and Sheridan Point the foreland is narrower and more sloping, while from Sheridan Point to Deep Landing it is broad and flat. Above Deep Landing the foreland terrace rises in elevation to a maximum of over 80 feet at Lyons Creek Wharf and it varies greatly in elevation, extent, and in soil types in this northern portion of its extent.

The Chesapeake Bay shore line of Calvert County forms one of its most interesting natural features. High cliffs of clay, sand, and gravel rise from the water's edge to elevations of 150 feet or more. The larger streams have cut through these cliffs nearly to sea level, and they have brought to the coast line loads of sand and silt, which the waves of the bay are distributing along the shore in the form of sand bars and sand spits. Along the greater part of the Chesapeake Bay shore line active wave cutting is taking place and the land area is being encroached upon at a rate varying from a few inches to several feet per year, depending largely upon the exposure of any particular area to wave action. The streams of any size in Calvert County flow into the Patuxent River with but two exceptions, Parker Creek and Fishing Creek. This fact, considered in connection with the general presence of forelands along the Patuxent and their absence along the bay, bears testimony to long-continued wave cutting on the bay shore, resulting in the destruction of formerly existing forelands, as well as causing large and continued inroads upon the main upland. Old survey records and natural phenomena like those cited above prove that the Atlantic coast line is gradually sinking below sea level throughout the entire distance from Maine to the Carolinas, so this land destruction must be anticipated along exposed shores for many years and probably for centuries to come.

The streams of Calvert County which flow into the Patuxent River constitute the major part of the drainage area of the county. Their head waters are uniformly found near the Chesapeake Bay shore and they flow south or southwest into estuaries branching off from the Patuxent. The valley walls are uniformly steep and poorly adapted

to cultivation, while the stream bottoms are usually narrow, flat, and wet, and adapted to pasturage more than to any other agricultural use.

Along the lower courses of the larger streams there are found some notable exceptions to the general rule of steep, sloping, wooded valley walls. Beginning just above where the stream proper empties into its tide-water estuarine portion are low-lying, flat-topped terraces, rising to an elevation of from 40 to 60 feet. If the surface of these terraces or terrace remnants is followed toward the Patuxent River, it will be found to descend to slightly lower elevations and finally, in many instances, it is continued along the Patuxent itself by the foreland areas already described. In fact the foreland is essentially a terrace formed along the Patuxent similar to the stream terraces farther inland.

The usual elevation of the foreland and stream terraces above tide water is about 30 feet in southern Calvert County, while in the northern part it rises to about 60 feet, as shown along Lyons Creek west of the railroad bridge. This rise is accomplished in a distance of about 30 miles, indicating an average slope of about 2 feet per mile. This same slope is indicated by similar deposits along the western shore of the Patuxent, by the slope of another deposit (the Leonardtown loam) in St. Mary County, and again by the slope of the fragments of Leonardtown loam areas found in Calvert County. Near Frazier the Leonardtown loam is present at about 100 feet elevation, and near Sunderland at 160 feet elevation, giving a general slope of 2½ feet per mile. It is not to be inferred that these slopes are absolutely uniform, for local variations are frequently found, but the agreement of these general slopes on both sides of the Patuxent, and in two different formations, definitely show an elevation of the general land surface, greater toward the north and less toward the south, as one of the more recent geological events of the region. These changes of level will be discussed more fully under the consideration of the geology of the region.

From an agricultural standpoint these facts of physical geography are of greatest interest in connection with the results produced on the land surface. As a brief summary of the effects upon Calvert County, it may be stated that the continual action of storm waves along the bay shore will steadily, though slowly, cut away the land area at exposed points and deposit this material as sand bars and mud flats where sheltered positions or cross currents cause a slack-water area. The equally continuous erosion performed by the head-waters of all streams will wear away the upland surface and transport the derived materials to tide-water estuaries, where they will be deposited, forming mud flats and marshes and causing a general shallowing of all adjoining water courses except where tide and stream currents are strong enough to keep the channels open. Thus, exposed areas subject to rapid rain wash must be carefully tended, while the wearing

away of the bay shore and the silting up of bays along the Patuxent are inevitable, and affect both agriculture and transportation.

GEOLOGY.

Calvert County lies entirely within the Coastal Plain division of Maryland, and the geologic formations which enter into its structure are composed of unconsolidated clays, sands, and gravels, together with remains of organic life like the infusorial earths and the marl beds. They are still passing through the earlier stages of rock formation, and neither pressure nor cementation has progressed far enough to bind the incoherent masses into firm, solid rock.

All geologic formations of sedimentary origin are divided and subdivided into various groupings according to their age, as determined by the character of the fossil organisms entombed in them, and according to the sequence of the formations. Thus, the grand divisions of Archæan, Algonkian, Paleozoic, Mesozoic, and Cenozoic are divided again and again. Only strata of the Cenozoic age are represented in Calvert County, so only their subdivisions will be considered.

Era.	Period.	Group.	Formation.	Soil type.
Cenozoic	Pleistocene	Columbia	Cape May	Meadow soil. Sassafras sandy loam.
			Wicomico	Norfolk sand. Sassafras loam.
			Dunkirk	Norfolk loam. Leonardtown loam. Susquehanna gravel. Windsor sand. Norfolk sand.
	Neocene	Chesapeake	Nomini	No soil areas.
			Choptank	Windsor sand. Norfolk sand.
			Calvert	Sassafras loam. Basal clay.
	Eocene	Pamunky	Nanjemoy	No soil area.
			Aquia	No soil area.

The oldest strata found belong to the Pamunky group of the Eocene. They consist of greensands, which outcrop along the Patuxent River and its tributaries from the vicinity of Ferry Landing northward to the county line. They reach the surface as outcrops, which form no surface features and no soils. Over this group is found the Chesapeake (of Neocene period), which is subdivided into three formations. The lowest, the Calvert, consists of layers of infusorial earth, which is made up of siliceous skeletons of animals and plants, living in an ancient sea, and of clays and silty sediments deposited in that sea. The only surface occurrence is in the form of a modified type of Sassafras loam. For the most part its rôle is to form the basal structure upholding the soil proper of the county. The next formation is the

Choptank, composed of fine and medium grained sands, and containing marl beds. The surface exposures contribute to the Windsor sand and form the main part of the Norfolk sand. Above the Choptank occur the Nomini strata, which form no extensive surface feature and thus give rise to no soil type.

These subdivisions of the Eocene and Neocene, after their deposition as marine sediments, one above the other in a nearly horizontal position, have been lifted above sea level by a slow elevation, which was greater toward the northwest than toward the southeast. The strata were tilted by this movement at a slope of about 11 feet per mile, and, after subsequent erosion, their upturned edges appeared at the surface in succession—the oldest, Eocene, toward the northwest, and the three Neocene formations in succession toward the southeast. After the end of the Neocene period the formations could have been seen overlying each other like a slanting pile of boards.

After this the land surface of the entire county was again submerged to a different depth and extent than in the earlier sea, and much more recent (Pleistocene) deposits have been laid down over the upturned beveled edges of the older formations. In this way there arose what is known as an unconformity, since the newer layers do not conform to the attitude of the older ones. A lapse of considerable time, accompanied by erosion of the old surface, is thus recorded.

It will be seen from the table above that the Eocene has no soil equivalent, because buried too deeply under more recent material. Even the Neocene, with its three formations, plays but small part in the soils of the present time. Almost the entire land surface is derived from the three formations of the Columbia group of the Pleistocene period. These three divisions are the Dunkirk, the Wicomico, and the Cape May, named in the order of their deposition.

The oldest (Dunkirk) formation exists as an almost continuous sheet of gravel, clay, and loam, covering the upland portions of the county. According as the component materials differ in texture and structure, depending upon the origin of the materials and upon the methods and conditions of their deposition, they give rise to the Norfolk loam, the Leonardtown loam, the Susquehanna gravel, the Windsor sand, and the Norfolk sand. The last two of these soils also occur as derivatives from the Choptank formation of the Chesapeake group.

The Wicomico, which occurs as a fairly well-defined terrace along the Patuxent and its tributaries, gives rise to the Sassafras loam over the main terraces and occasionally to small areas of Norfolk sand, where these terraces are continued inland along the larger streams.

The latest-formed Cape May terrace presents two characteristic soil types—the meadow areas of the foreland and the Sassafras sandy loam.

It will be noticed that several of the geologic formations give rise to two or more soil types, and that some of the soil types are derived

from two or more geologic formations. This emphasizes the fact, already noted, that the geologic classification of sedimentary rocks is based upon the time when the material was deposited, that is, upon the relative age as shown by the stage of development of life forms rather than upon the character of the material. The soil classification is based upon the character of the material without regard to its age. An ideal section showing the arrangement of the soils is shown in fig. 17.

There are several interesting problems regarding the origin and deposition of the Pleistocene deposits. The beginning of the Pleistocene stage of deposition was marked in Calvert County by the contribution of rather coarse sand and gravel containing some bowlders of such large size that flowing water could not carry them. They could have been brought to their present location only as débris frozen into or borne upon the surface of floating ice cakes. Some of these bowlders found in Calvert County are very interesting, as they show the source of the material, and consequently give some idea of the land area existing at the time of their deposition. Along Hunting Creek a bowlder was found which came from the granite area near

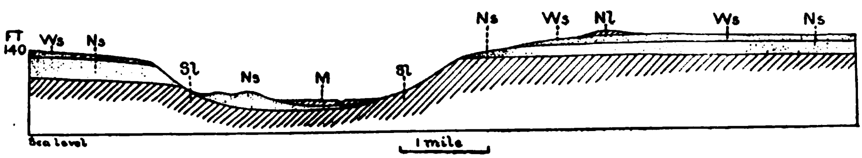


FIG. 17.—Section across Hunting Creek: *Ws*, Windsor sand; *Ns*, Norfolk sand; *Sl*, Sassafras loam; *M*, Meadow; *Nl*, Norfolk loam.

Ellicott City. It possesses the same peculiar texture as that granite—the large pink feldspar crystals surrounded by smaller-sized crystals of other component minerals. There are also found bowlders of other rocks, notably gabbro-diorite, a dark green or black rock derived from the same general region. The presence of these bowlders not only gives some idea of the land surface existing in this former geologic time, but their transportation by floating ice also gives some idea of the climatic conditions then existing. The layer of material bearing these bowlders, when now exposed, gives rise to the Susquehanna gravel.

After the deposition of this gravelly layer, clay and silt were brought in. The peculiar structure of the Leonardtown loam is due to the form this deposition took in its earlier stages. Clay pebbles and clay bowlders, probably derived from a shore line by wave action, were rolled together as the first deposit over the gravel and interbedded with sand and small gravel. When these were firmly packed down by the weight of accumulating sediments the clay pebbles were flattened out into lense-shaped nodules, and the resulting soil structure produces the effect of a heavy clay subsoil with sand partings. This

feature and its result are described under the Leonardtown loam soil type.

The Leonardtown loam deposit was succeeded by silty and sandy materials, giving rise to the Norfolk loam. After this the entire area was slowly elevated above water level and stream drainage was established over the newly formed surface. In many cases these streams closely followed the stream beds occupied during Neocene times, as these were only partly filled in during the Pleistocene submersion. As erosion began again the newly deposited materials were removed, together with older Neocene strata, and terraces were built near the mouths of the new streams while other deposits were made in the larger drainage systems like the Patuxent River. As the gradual elevation of the land proceeded, the erosion and deposition continued and the terraces of the Wicomico age, whose fragmentary remains are found still clinging along the Chesapeake and Patuxent shores and recognized as Sassafras loam soils, were formed. As the latest stage of this action, the foreland areas of the county, the Sassafras loam and meadow soils, were formed during the Cape May stage. These low-lying terraces were constructed along the Patuxent and probably also along the Chesapeake, though subsequent wave action has largely destroyed them there. At this time the deeper waters were receiving clayey materials and the shallow ones sand and silt. This area is slowly sinking again with most of the Atlantic coast, though the motion can be detected only by careful observations extending over long periods of time. The usual process of weathering, erosion, transportation, and deposition are in progress, and strata now are being formed which succeeding ages may sometime have an opportunity to study and classify.

SOILS.

The soils have about the following areas:

Areas of the different soils.

Soils.	Acres.	Per cent.	Soils.	Acres.	Per cent.
Norfolk sand	58,800	42	Leonardtown loam	7,950	6
Windsor sand	24,500	18	Norfolk loam	5,220	4
Meadow	15,800	11	Susquehanna gravel	3,900	3
Sassafras sandy loam	10,900	8	Swamp	3,600	2
Sassafras loam	8,850	6			

NORFOLK LOAM.

Norfolk loam is found in irregularly shaped areas on the highest uplands near Port Republic, Prince Frederick, and Mount Harmony. These scattered tracts of Norfolk loam represent an area of the soil which must have been much greater at some former time, but which

has been largely removed by active stream erosion, which still continues.

The areas as they exist form flat-topped or gently undulating divides between stream courses, sloping away on all sides toward the stream valleys. They are frequently bordered by exposures of the barren-clay subsoil of the formation, which is being washed away by the heavier rain storms with such rapidity that vegetation is unable to maintain itself. In many cases the clay scald thus formed descends to a ledge of iron-cemented sand and gravel or to a distinct gravel bed. Such an occurrence can be found about 1 mile south of Prince Frederick along the main highway.

The soil itself consists of a fine sandy to silty loam, having an average depth of about 10 inches. The subsoil is a heavier, sandy, yellow loam or, in some cases, a yellow loam. It varies in thickness from about 20 inches to over 3 feet.

This soil is usually cultivated over the entire area where it occurs, so that all natural tree growth has been removed. Corn produces a good crop upon this soil, and it was noticeable that during the exceptionally dry months of August and September, 1900, corn crops on this soil were among the last to suffer. Wheat is also raised on this soil, and, while it is one of the best wheat soils of the county, it is not a typical wheat soil. On the other hand, tobacco does well upon this soil, both as regards the quality and the quantity of the crop. Norfolk loam is probably the best general-purpose soil lying in the upland portion of the county.

The following analyses show the texture of the soil and subsoil of this formation.

Mechanical analyses of Norfolk loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5159	1 mile NW. of Port Republic.	Yellow, sandy loam, 0 to 9 inches.	2.59	1.28	7.52	5.87	6.48	14.41	51.99	9.79
5160	Subsoil of 5159	Heavy, yellow loam, 9 to 30 inches.	2.40	1.02	6.15	5.36	5.57	10.32	50.71	18.19

LEONARDTOWN LOAM.

Leonardtown loam is a type of soil found extensively in St. Mary County and named from the county seat. In Calvert County the type is found chiefly in the forest country between Drum Point and St. Leonard Creek, though many small areas of this soil occur over the

uplands farther north. Like the Norfolk loam, only a small part of its original extent remains, the greater part having been removed by the universal stream cutting.

The surface of the Leonardtown loam forms a part of the nearly flat but gently sloping upland, and in any single area it is nearly horizontal or only slightly rolling. The individual extent of the tracts in the southern part of the county frequently contain about 1,000 acres of very uniform soil, while the areas farther north are much smaller, some of them comprising only a few acres of almost barren clay subsoil, for erosion has progressed to such an extent that only small remnants survive, and so rapidly in many instances that the surviving fragments furnish no soil of agricultural value. Such areas are occasionally selected as building spots because their slight elevation above the general level of the country gives good drainage facilities.

Leonardtown loam owes its origin to the deposition of clayey sediments on the bottom of an old estuary or marine area. This deposition over a large portion of the area did not take place in the usual method by a mechanical settling of fine sediment from suspension in water. Such a course gives rise to continuous homogeneous layers of clay, while the Leonardtown loam, where undisturbed by cultivation and by the action of frost, rain, and other atmospheric agencies, presents the appearance of an accumulation of clay lenses or nodules, imperfectly separated from one another by veins and pockets of sand interspersed with scattered pebbles.

A visit to the present cliff line of Chesapeake Bay in Calvert County will give some idea of the manner in which the clay lenses of the Leonardtown loam were derived. Wherever the waves are cutting on clay layers steep cliffs are formed, and the continual wearing near tide level undermines large masses of clay, which fall down within reach of the waves, where they are further broken into bowlders and pebbles or ultimately reduced to a fine mud. The mud is generally washed away to some distance and only settles to the bottom in comparatively still water, while the pebbles and bowlders of clay are rolled on the bottom of the bay through accumulations of sand and mud and finally come to rest, unless completely broken up, as a pavement of clay lumps interspersed with finer materials. The waters of Chesapeake Bay are so shallow that only small portions of its bottom lie below the zone of wave action, especially during the more severe storms. As a result, the clays are usually broken up very completely and only the finer sediments are deposited. Still, enough of the bowlders and pebbles survive, even along the shore, to give an idea of the general operation of wave forces and of the deposition resulting from such action. If the waters of the bay were deeper, the shoreward slopes more shelving, and the materials worked upon more resistant to wave action, it is easy to see that the result would be a quite general deposition of beds of clay pebbles.

The Leonardtown loam, over a large part of the area occupied by it, was deposited in just such a manner. The subsoil of this formation is mottled red, yellow, purple, and gray by the deposition of hydrated iron oxide in various proportions in irregular patterns. A close examination of this mottling shows that the darker colors outline a series of clay lenses lying with their shorter axes nearly vertical and with their edges overlapping like shingles on a roof. Some of the clay masses are very regularly lenticular; others are irregular; while in some instances this structure is only partially indicated. Along the laps of the clay lenses are little seams of sand, with occasionally pockets or masses of sand of greater extent. Some fine gravel is mixed with the sand.

The entire structure suggests the accumulation of a large number of clay masses which have become flattened through the pressure exerted by overlying materials. These clay masses were probably derived by wave action, rolled along a somewhat sandy shore line or sea bottom, and finally deposited in more quiet water. The formation is almost uniformly underlaid by sandy and gravelly layers from which the sand content might have been derived, and the amount of sand in a given mass decreases as the distance from the sand layer becomes greater.

This structure of the subsoil of Leonardtown loam is one of its marked characteristics, not only in Calvert County, but over larger areas of the same soil formation in adjoining territory. It indicates a marine or estuarine origin of the soil material, and shows that the soil was deposited as a pebble or bowlder mass of clay in water of a moderate depth. The agricultural significance of this peculiar structure is also marked.

The soil of the Leonardtown loam areas consists of a yellow, silty loam, containing scattered pebbles of small size. Its usual depth is about 1 foot, and it is underlaid by a clay loam subsoil having the characteristics already described. The total depth of soil and subsoil varies greatly, both because of differences in thickness of the original deposit and because erosion has removed the formation to different degrees in different localities. Originally it must have been about 20 feet thick on most of the area of the county. The Leonardtown loam subsoil acts as a heavy clay in its relationship to the circulation and retention of soil moisture, though a mechanical analysis of any given portion of it would show it to be a somewhat sandy loam.

Water, in circulating through soils and subsoils, depends for its rate of motion upon the size and arrangement of the spaces existing between individual soil particles. Thus, a coarse, sandy soil has less actual open space in a cubic foot of material than a fine-grained, compact clay has. But the soil pores are large, and the volume of space, compared with the area of the walls of the cavities, is much greater than in the clay soil. As a result, water moves more freely through

sandy soils than through clays. Sandy soils are incapable of retaining the high percentage of soil moisture usually found in clays when all other conditions but those of texture are similar.

With the Leonardtown loam the actual texture of the soil masses is largely modified in its influence upon the circulation and retention of soil moisture by the peculiar structure. Water, in passing through the subsoil, must pursue a very roundabout course, for the clay lenses are highly impervious, while the sandy joints permit of a much easier flow. Thus, the soil water flows from the surface of one clay lens to that of another, and is much more retarded in its progress than would be the case if the same materials were mixed in a homogeneous mass. As a consequence, the Leonardtown loam presents the agricultural features of a heavy clay soil while composed of the materials of a somewhat sandy loam. The peculiar structure also makes the subsoil more friable, and the Leonardtown loam is frequently spoken of as a brittle soil to distinguish it from more plastic masses of clay.

The natural growth common to the Leonardtown loam comprises the white oak, pitch pine, and, in low-lying wet areas, the sweet gum. The white-oak growths are such a common feature of this soil that it is locally known as "white-oak soil," while the fact that much of its area is covered with timber also causes it to be spoken of as "forest land." The Leonardtown loam is one of the heaviest soil types found in Calvert County, and with proper cultivation it should produce good crops of wheat and furnish fair pasturage and clover crops. It is too heavy for the production of the best grades of tobacco, and, consequently, it has not been utilized to the best advantage in the Maryland areas where it occurs when this crop is used as the standard of comparison in estimating land values.

The uniformly yellow appearance of the surface soil indicates a lack of organic matter, which should be supplied in the form of stable manures and by plowing under green crops, like crimson clover and cowpeas. Such a treatment would not only increase the actual supply of plant food, but would also improve the texture of the soil. Unless it is absolutely necessary that tobacco should be raised upon areas of this type, the application of lime should be tried in connection with stable manures and green fertilizers. The fact that tobacco is not largely raised on this soil should make this line of improvement much easier than on other types of soil to which tobacco is one of the crops best adapted.

The present production of wheat and corn on the Leonardtown loam is scarcely equal to the average of the county, and large areas of the formation are left to forest occupation, furnishing only scanty pasturage for a few head of stock. The soil is capable of considerable improvement, and should be cleared and farmed according to modern methods, especially in the production of grain and forage crops.

The fact that the peculiar structure of the Leonardtown loam sub-

soil influences its crop value to a great extent is well shown by the following mechanical analyses. The actual percentage of clay present is only slightly greater than that in the Norfolk loam, while the silt percentages are nearly equal. The arrangement of the clay in nodules and lenses and the accumulation of sand along the overlapping edges produce a more impervious subsoil than is the case where the entire mass is homogeneous, as is true of the Norfolk loam.

Mechanical analyses of Leonardtown loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5161	Frazier	Yellow silty loam, 0 to 8 inches.	2.94	Tr.	2.01	3.68	9.38	10.53	59.00	11.81
5163	1¼ miles NE. of Barstow.	Yellow silty loam, 0 to 10 inches.	2.58	Tr.	2.91	3.76	11.83	20.86	50.57	7.52
5165	1¼ miles W. of Dares Wharf.	do	2.58	1.12	4.30	5.84	10.42	17.04	46.53	11.98
5162	Subsoil of 5161	Clay loam, 8 to 30 inches.	2.61	.64	4.01	4.54	6.26	13.44	58.73	10.81
5164	Subsoil of 5163	Clay loam, 10 to 30 inches.	2.31	.93	2.20	3.51	11.22	11.43	47.14	21.09
5166	Subsoil of 5165	Clay loam, 10 to 40 inches.	2.12	.80	3.48	5.17	7.65	10.44	48.55	21.75

SUSQUEHANNA GRAVEL.

About 6 square miles of territory in Calvert County are occupied by a distinctly gravelly soil. The gravels usually appear on slopes in narrow bands and in isolated patches, but near Adelina and about 1 mile east of Ferry Landing considerable areas of the upland are occupied by medium-sized quartz pebbles very loosely coherent and mixed with little other soil material. Also along some of the slopes from the upland region to the lower levels, soil-creep and rain wash have spread considerable gravel over the slopes. This concentration of gravel is in part due to the exposure of gravel bands originally deposited along with other material and in part to the concentration of the gravel by the washing away of finer materials. The resulting soil condition is not very favorable to agricultural operations. The soil, such as it is, consists of from about 60 to 85 per cent or even more of rounded quartz pebbles, varying in size from that of a pea to several inches in diameter. Some finer material present gives a foothold for vegetation, and near Adelina corn and tobacco are raised on this soil. Where a heavier subsoil is present at no great depth a sufficient water content can be maintained to produce a crop under favorable circumstances of rainfall.

In other localities grapes are raised on soils nearly as gravelly, but it is done in a climate where the rainfall is greater and the seasons of drought not so frequent nor so prolonged. Irrigation would aid in crop production on this gravel soil, but it is not well situated nor of sufficient value to warrant so expensive a remedy. For the present, therefore, these soils are considered quite valueless for agricultural crops. Fortunately, there are no large areas and the total area is small.

WINDSOR SAND.

This soil formation lies along the lower portions of the stream divides in the southern part of the county and occupies the highest crests in the northern part. The surface of the formation is usually gently rolling, and the more level portions of the type are interrupted by numerous small, flat-topped hills covered by Norfolk or Leonardtown loam, or else consisting entirely of the barren subsoils of these formations which have been exposed by rain washing. In some parts of the area, notably between Battle Creek and the Patuxent, gravel knolls and slopes are found scattered through this soil formation.

The Windsor-sand type owes its origin to the exposure of the horizon of orange-colored sands and gravels of the Dunkirk age, described in the chapter on the geology of the county. This layer of material at one time formed an almost continuous sheet over all the upland part of the county, and when first built into the land area of the region it was covered by other sediments which have since been removed by stream action. The remaining portions of these other sediments, the Norfolk loam and Leonardtown loam areas which still exist, are surrounded by bands or areas of Windsor sand. In many instances it is still possible to trace the sands and gravels of this soil type to the edge of Norfolk loam or Leonardtown loam areas and then to observe their continuation under the heavier materials of those types. This fact is conclusive evidence in itself of the origin of the type, but the location of the type between stream heads and along divides, where erosion has been most active, and its general presence immediately over Neocene strata throughout the entire area corroborate the more direct evidence. The close similarity of the materials of the soil to those of the orange sand and gravel, in many cases amounting to complete identity, also supports this explanation of the origin of the type, that is, a definite layer of sedimentary materials has been exposed by erosion and worked over to form a definite soil type. This is not the only case to be found in the county, as is indicated under the discussion of Norfolk sand and Sassafras loam.

One marked feature of the Windsor sand area is the absence of surface streams. The incoherence and porosity of the soil allow the water falling on its surface to sink immediately to considerable depths, and the flow of water takes place as a gradual seepage along

the surface of slightly more dense materials lying under the sand and gravel of this soil. As a result stream channels are only sparingly present in the area, for absence of surface flow prevents the formation of stream ways, and the small washes formed by the most torrential storms are rapidly obliterated by the crumbling of incoherent margins or by the ordinary operations of cultivation.

The soil proper of the Windsor sand areas consists of a medium to coarse grained sand, usually containing considerable quantities of small pebbles. Locally, the material frequently becomes finer grained, forming a sandy loam type, but this is more usual near the boundary with some other type where rain wash has brought in finer local material. The subsoil is a rather coarse-grained yellow sand mixed with pebbles and broken iron crust, and usually very loosely coherent. The soil varies in depth from 8 inches to about 1 foot, while the subsoil may be 3 feet or 10 feet in thickness, depending upon the amount of the material originally deposited and upon the progress of what little erosion takes place over the area. It is very uniformly underlaid by the finer grained sands and sandy loams of the Choptank or Nomini divisions of the Chesapeake. The contact between the Windsor sands and the underlying material is frequently well shown in the deeper road cuts.

The natural growth of this type of soil in Calvert and near-by counties consists of forests of pitch pine and yellow pine, which give it a distinctive character so pronounced that where the forest still remains it is usually easy to recognize the boundaries and extent of the areas by the tree growth. It is also noticeable that the most sandy roads of the county are, with few exceptions, found in areas of Windsor sand soil.

In Calvert county this soil type has lately been adapted to peach orchards, and supports some of the finest peach orchards of the region. The fruit is noteworthy for its fine color and flavor, and peach orchards in the county remain in bearing for a period of twenty-five or thirty years. Tobacco produces a good texture of leaf upon this soil type, though the amount raised per acre is somewhat less than on heavier soils. In especially dry seasons the plants are more liable to "fire" on Windsor sand than on soils more retentive of moisture. The Windsor sand is well adapted to the production of early truck crops. Increased rapid transportation facilities should permit of the more general introduction of such crops on this and other light soil types in the county.

The inability of so light and porous a type of soil to maintain a sufficient amount of soil moisture for plant growth during periods of drought may be corrected in part by the more general use of green manures plowed under, crimson clover and cowpeas being well adapted to such uses.

The coarseness of the grains forming this soil is indicated by the analyses of typical soil and subsoil:

Mechanical analyses of Windsor sand.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5167	1 mile E. of Prince Frederick.	Coarse sand and gravel, 0 to 12 inches.	0.97	10.31	34.75	23.06	13.95	4.52	9.85	2.65
5168	Subsoil of 5167	Coarse sand and gravel, 12 to 40 inches.	1.02	8.88	30.92	20.62	13.68	5.10	15.28	4.55

NORFOLK SAND.

Norfolk sand is found along the sides of all the deeper stream cuts in the southern part of the county, and it occupies about 50 per cent of the land surface in the northern half of the county, covering slopes and upland alike, except where other upland soil types still exist in fragmentary areas.

The surface of this formation, when it occurs along stream valleys, is generally quite steeply inclined and often precipitous. As a result, most of the areas of this type in southern Calvert County are occupied by growths of pine, being too steep to permit agricultural operations. In the northern part of the county and along certain stream terraces, like those in the Hunting Creek Valley, Norfolk sand forms one of the most important soil types.

Norfolk sand, as a soil type, owes its origin to three different methods of derivation. The greater number of the areas of this soil found in Calvert County are derived from the outcrops of layers of sandy material deposited under water during Neocene and Pleistocene time. Two of the subdivisions of the Neocene sediments consist largely of medium-grained sands, interspersed with thin strata of clay and layers of shell marl. One member of the Pleistocene, found lying above the Neocene in many places, consists of a medium-grained sand containing small pebbles and considerable iron crust. Where these different layers of sandy material have been exposed at the surface through stream erosion, the various agencies of weathering, such as frost, percolating rain water, and organic growth, have modified the originally infertile sands so that they are capable of sustaining vegetation and have become true soils. So areas of the resulting Norfolk sand are found in the stream beds where these layers outcrop, and

over the upland part of the county where overlying materials have been removed.

This process of soil formation has occupied a long period, and while part of the sandy material was being worked over into soil where it lay, part of it was carried away by the streams and dropped along the stream courses and at tide water wherever the current was not swift enough to continue to carry its load of sand. The present shore line lies considerably below the level of the position it occupied when this action began, so the first deposits of this transported sand was in the form of terraces built far above the present mouths of the streams. With the relative lowering of the water level these terraces have been exposed to the agencies of the atmosphere, and these sands have come to form soils almost identical with the ones directly derived from the outcrops of the original material. Such terraces may be seen near Hunting Creek Bridge, along Lyons Creek, and in many other localities. Part of the sand was also carried down as far as the areas now occupied by the foreland portion of the county along the Patuxent River, and areas of Norfolk sand are found about 1 mile south of Deep Landing and just north of Ferry Landing. They represent a terrace built by the Patuxent, in most respects similar to those built by the smaller streams. A common peculiarity of all these terraces is that the sand is coarser and the gravel more abundant as one goes up the stream. This is due to the diminished strength of stream currents near their mouths and the consequent diminution of the size of the particles transported.

In the northwestern part of the county and, in general, north of the latitude of Huntingtown the sands of this soil type are not so coarse as farther to the south, and a sticky, clayey subsoil is reached at a less depth. This is due to the fact that the lowest division of the Neocene, the Calvert clay and infusorial earth, comes out at the surface, and the sandy materials which once covered it have been more completely removed. However, the sandy layers are still represented by small areas on the higher uplands, and the long continued and constant rain wash has spread a thin layer of sand even over the heaviest subsoils. This action is still in progress, and many acres of this soil type consist of rain-washed materials which have accumulated in hollows and valleys. The agricultural values of these different accumulations remain remarkably constant; so they have been classed as a single soil type, though varying considerably in origin and in geologic age.

Norfolk sand is a yellowish sandy loam of medium coarseness, containing a scattering of gravel in some instances and often mingled with broken fragments of iron crust. The soil has an average depth of about 9 inches, and is usually succeeded by a slightly heavier yellow sandy loam which may extend to a depth of many feet, as in the case of the areas weathered out from outcropping strata, or which may be

underlaid at various depths by much finer-grained material, as is frequently the case in northern Calvert County.

The natural timber growth is pitch pine, chestnut, and oak. The soil is one largely used for the cultivation of tobacco, and some of the best tobacco farms in the area are located on this type. On the other hand, a few farms located near the Patuxent River on this type are reported as not so successful in the production of the crop; for, while a large growth is secured, the quality is not of the best.

Norfolk sand, as represented by the finer-grained grades of northern and northwestern Calvert County, produces good crops of tobacco, and the type in general is also well adapted to the production of truck crops. The peaches raised upon this soil are of good color and bring good returns. Wheat and corn are raised on this soil in regular rotation with tobacco, but the Norfolk sand is a type distinctly too sandy for the production of the best grain crops. It is not sufficiently retentive of water to maintain the continuous growth necessary to bring grains, especially wheat, to maturity.

The increased facilities for rapid transportation, recently acquired in northern Calvert County, should lead to a more general use of this soil for market gardening purposes. It is one of the typical truck soils of the Atlantic seaboard.

The slight gradation in the texture of this soil type is well shown by the following analyses. The finest-grained soils are found toward the northern extremity of Calvert County, while the coarsest sands are found near its southern end. The intermediate texture of the Hunting Creek sample is quite marked.

Mechanical analyses of Norfolk sand.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5169	One-fourth mile N. of St. Leonard.	Medium brown sandy loam, 0 to 10 inches.	1.42	1.06	6.08	10.06	51.44	10.84	15.40	3.65
5171	1 mile E. of Hunting Creek Bridge.	Orange sandy loam, 0 to 9 inches.	1.33	.58	2.49	6.28	48.36	20.99	16.33	3.51
5176	One-half mile N. of Mount Harmony.	Yellow sandy loam, 0 to 9 inches.	1.70	Tr.	1.33	2.36	47.38	26.20	16.95	3.68
5170	Subsoil of 5169......	Orange sandy loam, 9 to 30 inches.	2.11	.70	4.00	7.08	51.98	7.27	16.51	10.66
5172	Subsoil of 5171......	....do..............	1.11	Tr.	3.06	6.09	49.73	17.16	16.14	6.26
5177	Subsoil of 5176......	Yellow sandy loam, 9 to 30 inches.	1.48	0.00	Tr.	2.40	43.33	26.59	19.65	6.59

SASSAFRAS LOAM.

No large single areas of Sassafras loam are found, but many small tracts occur over almost the entire county. They are found more numerously and in larger areas in the northern part of the county than in the southern.

Sassafras loam in Calvert County is derived from two separate sources. The lowest member of the Chesapeake group, the Calvert, is made up of beds of infusorial earth and clay, and where these reach the surface the resulting soil is a slightly sandy loam derived directly through the action of atmospheric agencies upon the clay and infusorial earth strata. The areas of soil thus formed are found along the slopes of stream valleys and are usually merely long narrow strips of a heavier soil, separating the higher sandy soils from low sandy terraces or from meadow lands in the stream bottoms. Frequently the horizon, which would be occupied by this soil type, forms a steep cliff of clayey material unadapted for agricultural purposes. This zone of Sassafras loam does not always show the soil formation in its most typical character, since it lies in a position to catch much of the sandier material washed down by rains from higher levels. In these cases the soil is more sandy than in type localities, but the subsoil is the usual heavy clay found elsewhere throughout this formation.

Lying along the stream valleys and along the Patuxent slope are flat-topped terraces, built up in recent geologic times from materials which have been derived from the Calvert clays and reworked into later deposits. So far as soil values are concerned these materials form the same soil types as when they composed part of the Neocene strata, though they now occur as terrace forms. A terrace of this character is well developed at about 80 feet elevation just west of the head of tide water on St. Leonard Creek, another is found just southwest of Dares Wharf, and many more examples could be cited from localities along the Patuxent. The region lying just east of Lower Marlboro presents an area where the Sassafras loam terrace of later age rests against the outcrop of Neocene material, giving rise to the same soil type, and the resulting occurrence of Sassafras loam is one of the largest found in Calvert County.

The influence of this heavy clay material, as it occurs at Neocene horizons, is felt in the northern areas of Norfolk sand. The clay comes near the surface, under the covering of sandy soil, and in some cases forms sticky bands of small extent in fields otherwise uniformly covered by Norfolk sand.

The topography of the surface of this soil varies with its manner of occurrence. In the terrace areas it is flat topped or gently sloping, while in the outcrop areas it is more steeply sloping or even precipitous and considerably gullied by stream action.

The soil itself consists of a silty to fine sandy yellow or brown loam,

having a depth of about 10 inches. This soil is uniformly underlaid by a yellow loam of a finer texture than the soil, usually to a depth of 40 or 50 inches. In the outcrop areas of this type the subsoil grades down into the unweathered bluish clay of the Calvert formation, while in the terrace areas, as at Dares Wharf, the subsoil is underlaid by cross-bedded sands.

Sassafras loam is a type of soil well adapted to general farming purposes, and if it occurred in larger areas would form a marked class of farming lands. It produces some of the best corn crops aised in the county, and produces fair wheat yields. It is also cultivated in tobacco with good results. In other regions than Calvert County this soil supports excellent pear orchards and furnishes good crops of tomatoes and asparagus.

The following analyses give an indication of the texture of the Sassafras loam. The percentage of clay in this soil is less than that in either the Norfolk or Leonardtown loam.

Mechanical analyses of Sassafras loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5180	1 mile W. of St. Leonards.	Yellow silty loam, 0 to 20 inches.	2.67	0.84	4.07	4.38	6.48	12.72	60.72	7.80
5182	One-fourth mile S. of Dares Wharf.	Yellow loam, 0 to 9 inches.	2.35	.46	3.01	6.55	25.10	15.29	36.15	10.74
5181	Subsoil of 5180......	Yellow loam, 20 to 36 inches.	2.07	.49	3.94	3.78	4.36	8.17	54.67	22.39
5183	Subsoil of 5182......	Yellow loam, 9 to 30 inches.	2.37	.31	2.06	4.67	21.58	15.37	32.86	20.53

SASSAFRAS SANDY LOAM.

Sassafras sandy loam lies chiefly along the low forelands which border the Patuxent River, and is also represented by small areas near Plumpoint and along the lower course of Fishing Creek. The surface of this formation is usually flat and only gently sloping. It lies at an elevation of from 15 to 35 feet above tide level, and its location near tide water, together with its altitude and its crop values, makes it one of the most desirable soil types in the region. It forms a portion of the area included in the most recent geologic formations of the region and represents a deposition of fine sand, silt, and organic matter in the shallower waters of the latest stage of land submersion. A very similar process is being carried on at present along the coast line, where lagoons and stream mouths are being silted up after each rain storm. The present marsh areas along the Patuxent, with their

abundant growth of aqueous vegetation, serve as a filter, which entangles the sediment carried by the river and retains it, mingled with decaying vegetation, to form a soil much like the Sassafras sandy loam when a change in comparative land elevations shall expose these areas as portions of the land. So in former times, along the river shores, in the embayments formed by tributary streams, and where sand bars sheltered areas of shallow water, the materials of the Sassafras sandy loam were accumulated, and they now form a portion of the land well known for its fertility. Small areas of especially sandy soil lying within the boundaries of this type, notably near Point Patience, are still in the process of formation. The wind sweeping along a sandy shore line and against a low cliff picks up sand from the beach, and, when the direction of its current is changed by the cliff, eddies are set up which allow part of the sand to drop on the near-by fields. Small patches of a few acres in extent are made excessively sandy and their adaptation to crops is materially changed by this process.

Sassafras sandy loam may be defined as consisting of a medium to fine brown sandy loam, having an average depth of a foot or more. It is underlaid by a heavier type of yellow sandy loam to an average depth of about 4 feet, and this is often, though not always, succeeded by a gray or drab clay loam. This combination of soil textures gives rise to an easily worked soil sufficiently retentive of moisture to favor the production of grain crops, but not so heavy and wet as to exclude the cultivation of late truck crops and fruit. Tobacco is also raised on this soil, though it is not so well suited to tobacco culture as are other sandier types located in the county. Stock raising and dairying are carried on upon this soil type in a few localities in the southern part of Calvert County, while the cultivation of crops for canning factories is undertaken upon this type of soil in other localities. The natural forest growth has been removed from the Sassafras sandy loam, and almost the entire extent of the formation is under cultivation.

The following analyses of a typical sample of the soil and subsoil of this type show the sandy character of this loam:

Mechanical analyses of Sassafras sandy loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5184	One-half mile N. of Point Patience.	Brown sandy loam, 0 to 14 inches.	2.98	0.66	3.10	5.52	31.94	20.92	29.63	6.30
5185	Subsoil of 5184......	Yellow fine sandy loam, 14 to 30 inches.	1.76	.48	3.08	5.30	26.16	20.24	33.29	9.54

MEADOW.

The signification of the word meadow varies so greatly in different localities that it may be well to define its use in this report as referring only to low-lying, generally rather wet areas, having an approximately flat surface and best adapted to the production of grasses and to grazing.

In Calvert County, meadow areas are found along the bottoms of the larger stream valleys and on the lower-lying portions of the forelands bordering the Patuxent River. The chief difference between these areas is found in their extent. The stream valleys are narrow and steep walled, and the level or gently rolling portions of their bottoms are the only parts of the upland forming typical meadows. Even portions of these stream bottoms are so wet and ill drained as to fall in the general classification of swamps, as is the case with the lower courses of Fishing Creek, Parker Creek, and other large streams.

The meadow lands of the stream valleys owe their origin primarily to the action of the streams themselves. Channels have been and are being cut into the unconsolidated materials which constitute the region, and the changing locations of the larger streams have broadened these valleys. Then, too, local material contributed by every storm is carried part way from the upland to the sea and is left temporarily at different points along the valley. In some cases deposits of sand and gravel are formed; in others, clay and silt are deposited, and an irregular soil results. The common characteristic of this entire soil mass is its moist condition, resulting entirely from its position relative to stream drainage.

Upon these meadow areas a rank growth of poplar, sweet gum, alder, and a few pines and oaks are found, generally overgrown by climbing vines and interspersed in the more open portions by banks of ferns and areas of coarse, rank grasses. The position, altitude, and moisture conditions are not favorable to the cultivation of crops, and the only real use made of these lands is to turn farm animals upon them to graze. The open winters of the region permit of almost constant grazing, though some of the meadow areas are frequently flooded to such an extent that they become inaccessible.

The meadow lands lying along the forelands are somewhat different. They comprise low-lying areas which, on account of the fine texture of the soil or because of their position near water level, are not so valuable for general agricultural purposes as the prevailing soil type. However, these meadow lands are frequently cleared and fair crops, especially grain crops, can be raised on this soil.

The foreland meadows owe their origin to the deposition of fine silt and clay when the area was submerged and to the partial establishment of natural drainage since they became a part of the land area. They are flat or gently rolling, and there is no marked rise in elevation

in passing from the meadow land to the Sassafras sandy loam. There is, however, a marked change in soil texture in most cases.

The foreland meadows generally have a depth of about 1 foot of gray or drab-colored silty or clayey loam underlaid by 3 or 4 feet of drab clay. This is frequently succeeded by gravel and sands extending downward to sea level. The clay, though tough and plastic when wet, will leach out and fall apart if long exposed to the action of the rain and frost. This same soil type, if lying farther above permanent water level, would correspond closely in texture and crop values to Sassafras loam. These meadow lands are largely covered with growths of sweet gum, water oak, and other water-loving trees. Where cultivated they produce a fair crop of wheat or grass, but are not adapted to the culture of fruit, truck, or tobacco. One peach orchard seen on this soil type looked sickly and the fruit was not well colored.

Artificial underdrainage and a resort to liming would improve this land and help to bring it into a fair state of productiveness. Wheat, corn, and grass should be its chief crops. The valley meadows, on the other hand, are only adapted to grazing, and the wild grasses now produced are not particularly nourishing.

SWAMP.

The mouths of nearly all the larger streams in Calvert County are marked by areas of marshy land. This condition is brought about through two chief causes. In the first place sand and clay derived from the upland are being deposited near the mouths of all the streams, and the land area is growing slowly. The first step in this growth is the shallowing of water areas through deposition, then vegetation gains a foothold, and swamp areas grown up to reeds, calamus, and marsh grasses are formed. But this building up is impeded to a slight extent through this region by the slow sinking of the land. However, the silting up of streams is progressing so rapidly that areas which once permitted navigation by small boats now form tide flats and marshes. This is notably the case along the lower course of Hunting Creek and at the mouths of streams flowing into the Patuxent. Along the bay shore the waves are cutting away the coast line so rapidly that marshes are not formed so extensively. The mouth of Fishing Creek and that of Parker Creek are swampy, and the sand bar built up by wave action at Covepoint incloses a marshy lagoon.

These swampy areas and the more extensive marshes formed by the silting up of the Patuxent River do not form a part of the agricultural area of the county. In some places diking and drainage might reclaim parts of the swamp areas. The swamps could be made to furnish a supply of muck and peat for composting with stable manures and lime, which would form a very desirable fertilizer. In their present state the muck and peat are not sufficiently decomposed to furnish an immediate supply of plant food.

CONDITIONS OF AGRICULTURE.

The consideration of the possibilities of development of any agricultural region must depend upon the soil, the climate, and the transportation facilities, combined with the physical and mental energy of its inhabitants, and upon the social and industrial conditions.

The soils of Calvert County were first brought under cultivation when the entire area farmed in the present limits of the United States constituted but a narrow fringe along the tide-water portion of the Atlantic seaboard. They have been tilled continuously for nearly two hundred years under various conditions and with varying success. The early colonists began the cultivation of tobacco with their first season's work; it was planted to the exclusion of food crops, and an early enactment of the colony provided that 2 acres of corn must be planted for each person in the colonist's family, in order that they should have a grain crop to live upon. This indicates the extent to which the tobacco crop held sway even at the beginning of the history of the county. Calvert County, in common with the other southern Maryland counties, remained a tobacco-raising region of eminence for nearly two centuries. The crop was cultivated by means of slave labor, and large plantations were the rule rather than small farms. During this period the type of tobacco was developed which has secured a place in the trade world under the name of Maryland pipe tobacco. This tobacco is in demand for the French export trade, and the region is called upon at present to furnish from 15,000 to 18,000 hogsheads of about 800 pounds weight each year. Of late years increasing quantities of Ohio tobacco have come in competition with the Maryland product.

The civil war brought about an entire change in the social and economic relations in the county, and consequently in its agricultural activities. Many plantations which were admirably tilled by large forces of hands speedily deteriorated, since the labor necessary for their cultivation became very scarce, and at times even could not be hired. The large plantations were either mortgaged heavily in an effort to keep them under cultivation, or else portions of them were allowed to go out of cultivation. Even the sale of land which was no longer needed under the new order of affairs was difficult, since the great majority of the community suffered from the same causes. At the same time the tide of Western immigration carried settlers past the eastern seaboard to cheap Government lands in the West, and very few men of means came in from other localities to aid in the further development of this region.

As the Western country was settled its enormous grain crops, produced at a minimum expense for fertilizing and cultivation, came into direct competition with the corn and wheat crops of the East. Thus, the crops which, in the absence of abundant hand labor, could

be produced to best advantage came upon a market fully stocked with grain produced under less costly conditions.

These conditions of labor and of market have tended to discourage and dishearten even the most capable and energetic. On the other hand, the natural advantages of climate and abundant food supply have encouraged improvidence on the part of the wage-earners and laborers. Where wants are few and easily supplied the tendency toward energy of plan and action is dwarfed. Thus, some of those most in need of advancement have contented themselves with a bare existence when abundance might have followed from better directed and more sustained efforts.

The low productive power of many areas besides the one under consideration may be ascribed to the same general causes. Methods of agriculture must be improved, the intensive rather than the extensive system of farming followed, a sustained effort for the production of special crops undertaken, and the adaptation of special soils to special crops must be better understood and more fully practiced.

The large markets of the East are accessible by boat and rail communication. Only a single one is at present patronized to any extent by the producers of Calvert County. Using the peach crop as an example, instances have been known where large and fine crops of peaches have been marketed at a loss on a single market which was glutted, while other markets only a little less accessible were far from being stocked.

Such changes as will enhance the value and productiveness of the county must come slowly, supported by the experience of the most progressive and best equipped inhabitants. Such changes are in progress, and some of them have passed the experimental stage. Others have been planned but not undertaken. It is to be hoped that increased knowledge of the conditions both within and without the county may enable its inhabitants to realize the opportunities which they possess and from which they may profit.

CLIMATE.

The following table of climatic elements, compiled from the Maryland Weather Service, Vol. I, gives an indication of the average conditions to be expected in Calvert County. The station at Solomons represents conditions near sea level and near large bodies of water; that at Jewell represents the upland conditions.

Climatological data for Calvert County.

SOLOMONS.

Month.	Mean monthly and annual temperature.	Mean maximum temperature.	Greatest departure above.	Greatest departure below.	Mean minimum temperature.	Greatest departure above.	Greatest departure below.	Mean daily range.	Highest recorded temperature.	Lowest recorded temperature.	Mean monthly and annual precipitation.	Maximum monthly and annual precipitation.	Minimum monthly and annual precipitation.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	In.	In.	In.
January	34	41	+7	−7	28	+6	−10	13	66	4	2.6	5.1	1.5
February	36	43	+2	−7	28	+2	− 9	15	67	− 5	4.0	6.4	1.3
March	44	52	+6	−4	35	+6	− 8	17	82	18	3.2	4.7	1.2
April	53	62	+2	−2	45	+2	− 4	17	88	28	3.5	5.5	1.2
May	65	74	+5	−3	56	+5	− 2	18	100	41	3.9	4.6	2.4
June	74	83	+2	−3	66	+4	− 2	17	99	49	3.3	5.7	0.9
July	78	86	+2	−2	70	+1	− 3	16	99	57	4.2	7.4	2.3
August	78	86	+4	−2	70	+2	− 2	16	98	59	3.2	7.9	1.0
September	72	80	+5	−4	64	+3	− 2	16	98	46	2.0	3.2	0.5
October	59	68	+1	−2	50	+4	− 4	18	89	35	3.2	5.4	0.7
November	49	56	+6	−3	41	+4	− 2	15	77	23	3.0	4.7	1.9
December	39	46	+4	−4	32	+2	− 2	14	65	11	2.6	3.3	0.9
Annual	57	65	......	......	49	......	......	16	100	− 5	38.6	43.5	32.1

The last killing frosts in the spring have occurred as follows at Solomons: On April 20, 1897 and on April 28, 1898.

The first killing frost in the fall has occurred as follows at Solomons: On November 13, 1897.

JEWELL.

Month.	Normal monthly and annual temperature.	Highest recorded temperature.	Lowest recorded temperature.	Mean monthly and annual precipitation.	Maximum monthly and annual precipitation.	Minimum monthly and annual precipitation.
	° F.	° F.	° F.	Inches.	Inches.	Inches.
January	34	64	1	2.8	5.1	1.3
February	38	66	−14	3.6	5.6	1.2
March	42	80	11	4.8	8.4	2.8
April	55	94	23	4.0	12.2	1.2
May	64	95	38	5.1	7.3	4.2
June	73	99	45	3.7	5.7	1.0
July	76	99	53	7.0	19.9	2.5
August	76	97	50	3.4	6.9	0.9
September	70	95	41	3.7	9.2	0.9
October	55	83	28	3.7	6.2	0.4
November	46	78	21	3.3	6.6	0.8
December	38	68	8	2.9	5.6	Trace.
Annual	55	99	−14	47.9	65.7	36.2

The last killing frosts in the spring have occured as follows at Jewell: On April 20, 1897, and April 6, 1898.

The first killing frosts in the fall have occurred as follows at Jewell: On October 19, 1896; November 13, 1897, and October 28, 1898.

SOIL SURVEY OF KENT COUNTY MD.

By JAY A. BONSTEEL.

GEOGRAPHY.

Kent County occupies an area of 315 square miles, located in the northern portion of the Eastern Shore of Maryland. The county is separated from Delaware on the east by a line run by Mason and Dixon and marked by mileposts, set in the latter half of the eighteenth century. The western boundary of the county is formed by the upper portion of Chesapeake Bay, while the Sassafras River separates it from Cecil County, Md., and the Chester River divides it from Queen Anne County. Chestertown, the county seat, is the largest town, having a population of about 3,000. Washington College is located there. The county is located between the parallels of 39° and 39° 22′ north latitude, and between the meridians of 75° 45′ and 76° 16′ west longitude.

Both the Chester and Sassafras rivers are navigable within a few miles of the Delaware line, and these, with Chesapeake Bay, afford fine facilities for water transportation. The highest elevations above tide water are reached near the mouth of the Sassafras and near Kennedyville, where an altitude of 100 feet is attained.

PHYSICAL GEOGRAPHY.

Kent County is naturally divided into two main physical divisions. The greater part of the county consists of a low upland between 50 and 100 feet above tide level. This higher area is bordered along the Chesapeake Bay and, for a part of the distance, along the Chester River by low-lying forelands ranging in elevation from 10 to 40 feet above tide water. The line of division between the two areas is indicated by a well-marked cliff escarpment over a large part of the area, as at a point one-half mile southwest of Langford, though along the Chester River this feature is not so well shown. These two divisions not only differ in elevation, but each has its own well-marked soil types and its own agricultural conditions.

The foreland area is much indented and divided by tide-water estuaries branching from Chesapeake Bay or Chester River, while the upland area is only slightly cut into by tide water, but is everywhere seamed and dissected by stream courses. The foreland possesses few, if any, streams capable of furnishing water power for milling purposes, while many of the upland streams have long been used as sources of power. The bays and inlets of the lowland facilitate water

transportation, while they make overland communication circuitous and slow. The upland is well supplied with highways, which easily cross the stream courses and cover the county with a good series of roadways, while it is necessary to descend to one of the larger waterways to secure access to water carriage. These facts, combined with soil differences, serve to accentuate the mere differences of elevation.

The main divide existing between the drainage systems of the Chester and Sassafras rivers is a poorly marked flat upland, which merely indicates the points to which stream heads have so far eroded, rather than a sharp division line dividing two well-defined stream systems. In the eastern part it consists of poorly drained, nearly flat areas, where water stands as though undecided which course to take. To the west, on account of the greater fall and the shorter distance to tide water, the streams have established better defined courses and the upland is well drained.

Nearly all of the streams which do not actually flow into tide-water estuaries descend to deeply cut, flat-bottomed areas, which are usually swampy. These areas have been actual tidal embayments at a recent geologic period, but the rapid deposition of material by the streams themselves has built up large extents of marsh land. Even the Chester and Sassafras rivers have suffered in this respect, and navigation has been impeded by this continued deposition of sand, silt, and clay brought down by the minor streams. Dredging has been resorted to in some instances to keep open the approaches to important landings along the rivers.

None of the streams of Kent County have cut deep gorges, except near their mouths, and none of them have very rapid currents. Some of the larger streams which maintain their flow during the entire year have been utilized for local milling purposes.

Along wave-beaten shore lines the force of the attack is cutting away cliff lines and the lateral sweep of the waves is slowly transporting the materials thus derived to more sheltered areas, where sand bars and sand spits are being built up. Some of these are forming across the mouths of various estuaries, forming landlocked harbors of small extent. Behind the bars the material brought down by streams is being deposited, and the estuaries still in existence are slowly being brought to the state of those already filled to the marsh condition.

GEOLOGY.

Kent County lies entirely in the Coastal Plain of Maryland, and its surface features are due almost exclusively to the sediments deposited in Pleistocene time and since elevated above sea level and weathered and eroded until the present time. The basal structure of the county is made up of greensands of Cretaceous and Eocene age, and these sands have contributed to the materials built into the newer formations. The Norfolk sand type of soil owes its origin almost exclusively to the reworking and redeposition of these older sands. The

other loams and clay loams of the county fall within the later divisions of the Pleistocene, as outlined in the Calvert County report.

The correlation of the soils with the geological formations of Kent County shows that the Sassafras loam, the Sassafras gravelly loam, the Susquehanna gravel, and part of the Norfolk sand and meadow occur in the Wicomico division, while the Elkton clay, part of the Norfolk sand, and the large foreland meadow areas belong to the Cape May division. Physiographically, the Wicomico comprises the interior upland portion of the county, while the Cape May includes the bordering foreland areas.

SOILS.

SASSAFRAS LOAM.

Sassafras loam covers a total area of over 130 square miles (87,000 acres), lying wholly within the upland portion of Kent County. This soil is typically represented both in Kent and the Coastal Plain portion of Cecil County, though it is by no means confined to these areas nor to the Eastern Shore of Maryland.

As a rule, the surface of this formation in Kent County is slightly rolling and the areas possess sufficient irregularity of surface to allow of good natural drainage. In some instances small saucer-shaped depressions still exist unaffected by the general stream erosion, but short surface ditches or, better, a well-like drain down through the subsoil to underlying sandy layers will suffice to bring these wet places into good cultivation.

The soil proper consists of a fine brown loam, which is often slightly sandy, especially in the eastern part of the county. It extends to an average depth of about 9 inches and is underlaid by a uniform yellow loam subsoil. The subsoil varies in thickness from about 20 inches to a maximum of 5 or 6 feet. It forms a supply reservoir capable of maintaining a large amount of soil moisture during the growing season, and it is as important a factor in the productivity of this soil type as the soil proper. Underneath the true subsoil is usually found a layer of rather coarse gravel mixed with large-sized bowlders and coarse sand, frequently cemented to a solid mass by the long-continued deposition of hydrated iron oxide. When in this state the gravel band is known as hardpan.

Below the gravel layer there is usually found a bed of medium to coarse red sand mixed with fine gravel and interspersed with seams and beds of gravels. Sometimes masses of clay are incorporated with this material. These lower-lying, coarser materials have little effect upon the higher upland areas of this soil type beyond furnishing a natural underdrainage, but where the higher-lying surface becomes thinner, as it descends toward stream beds, the lower-lying, coarser material sometimes mingles with the finer-grained soil material sufficiently to produce a different soil condition.

Sassafras loam is carefully cultivated over almost its entire extent,

hence little, if any, of its original tree growth remains to indicate what the natural productivity of the soil brought forth.

The soil is well adapted to general farming. It lies between the limits of the heavy clay soils and the light sandy soils, and is capable of producing a wide range of crops in generous amounts. It forms the typical corn and wheat soil of the county, producing wheat at a rate of from 15 to 20 bushels per acre, the quantity varying with the season and with the state of cultivation of different farms. Corn yields about 50 bushels per acre. Large orchards of Kieffer pears are found on this soil, and while peach raising is not so largely followed now as formerly, many peach orchards, both old and new, are found on the Sassafras loam. The production of tomatoes, peas, and of other canning crops is also carried on on this soil, while extensive asparagus beds are found in its area. Stock raising and dairying are followed, and many flocks of sheep are to be found, chiefly upon this soil formation.

The diversity of interests already supported by this soil mark it as a highly valuable farming area for general purposes.

The texture of the Sassafras loam is shown by the following mechanical analyses:

Mechanical analyses of Sassafras loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5187	One half mile W. of Betterton.	Brown loam, 0 to 8 inches.	3.32	Tr.	0.98	0.79	1.28	18.55	66.88	8.28
5189	Three-fourths mile NW. of Langford.	.....do	3.15	0.38	1.94	1.46	2.20	18.63	61.30	10.18
5188	Subsoil of 5187.......	Heavy red loam, 8 to 36 inches.	2.42	0.00	Tr.	.83	.82	16.51	63.62	15.76
5190	Subsoil of 5189.......	.....do	2.99	Tr.	1.55	1.22	1.85	16.72	62.36	13.30

SASSAFRAS GRAVELLY LOAM.

In many instances where the slope from higher to lower levels is not steep enough to bring the heavy gravel band of the upland region to the surface as an outcrop, areas of decidedly gravelly soil are found. These owe their origin to the fact that the Sassafras loam is not so thickly developed over the areas as to cover in and obscure the underlying gravel completely, though enough of the finer material is present to constitute by far the larger part of the soil mass. Such areas are usually found on long, gentle slopes near or between the larger stream courses. Large tracts occur northwest of Millington and northwest of Chestertown, while smaller areas are found throughout the upland part of the county.

The surface of this soil type is generally sloping or rolling, and some of the smaller areas occur as bands along the gently sloping banks of smaller streams and near stream heads.

The soil consists of a brown, slightly sandy loam, containing a scattering of gravel, which often amounts to 10 per cent. This is underlaid by about 2 feet of heavy red or reddish-yellow loam, also containing gravel, which is, in turn, followed by red sand and gravel mixed with iron crust. The less depth of heavy subsoil in this type and the consequent influence of the underlying sands and gravels are more important factors in differentiating it from the Sassafras loam than is the presence of the gravel in the soil. All these factors, however, combine to constitute a lighter soil type and to make it adaptable to other agricultural purposes.

Like the Sassafras loam, this soil comprises lands, chiefly cleared, which have long been cultivated. The absence of natural tree growth precludes any conclusions drawn from natural conditions.

Sassafras gravel loam approaches more nearly to a strictly corn-producing type than to a wheat land, and it is also suited to the production of late truck crops, like those used in the canning industry. Sugar corn, tomatoes, peas, and other crops produce well on similar soils, and the climate of Kent County favors these crops. Nursery stock and small fruits can be raised on this type of soil, and, while the wheat crop usually produces best on heavier soils, a fair crop can be raised on the Sassafras gravelly loam.

The following table shows the sandy and gravelly character of this soil, at the same time indicating the presence of sufficient silt and clay to form a truly loamy soil. The mechanical analyses gives the texture of the fine earth only. A separate determination of the larger gravel was made.

Mechanical analyses of Sassafras gravelly loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5197	2½ miles NW. of Chestertown.	Brown sandy loam, 0 to 10 inches.	3.59	2.42	6.27	5.34	4.34	8.50	58.69	9.91
5199	1 mile NW. of Millington.	.....do...............	2.55	3.24	10.02	8.34	8.85	12.35	45.10	9.88
5198	Subsoil of 5197.......	Red loam and gravel, 10 to 24 inches.	2.91	1.36	3.99	4.60	3.29	9.08	56.16	18.47
5200	Subsoil of 5199......	Red loam and gravel, 10 to 36 inches.	2.14	3.27	10.43	8.57	10.91	13.88	36.42	14.37

Coarse gravel, from 3 to 5 per cent in all four samples.

SUSQUEHANNA GRAVEL.

Along the slope which separates the upland portion of Kent County from the foreland areas and along the steeper slopes down to stream areas the stony and gravelly layer underlying the Sassafras loam almost universally reaches the surface and its materials mingle with those of overlying and underlying formations. Thus, a narrow band of steeply-sloping, stony soil is formed which forms a marked line of separation between other distinct soil types. Originally this layer of gravel could have formed only a narrow band of a width equal to the extent of the beveled edge reaching the surface on the slope, but long continued freezing, thawing, rain washing, and the action of gravitation have spread the stone and gravel over much wider areas and produced a stony soil.

This soil contains from 20 to fully 50 per cent of coarse gravel in certain places. The other finer material may be sandy, especially on slopes where the underlying sand formations reach the surface, or it may be composed of silt and clay washed down from the Sassafras loam.

The stony areas are frequently cultivated to the same crops as the other soils above and below, but they differ from them largely in ease of cultivation and in the varying degrees of productivity. Usually they are not sufficiently extended to warrant any special treatment or crop, though some of the slopes closely resemble soils devoted to vineyard interests in other localities.

It would not be possible to remove completely even the larger stone from these areas, as the supply from the gravel bands is almost inexhaustible, and new crops of stone would work out into the soil so long as cultivation and atmospheric influences have access to this material.

NORFOLK SAND.

Norfolk sand covers a total extent of nearly 30 square miles (about 20,000 acres) in Kent County. The largest single area of this soil type occurs in the southeastern part of the county. Here the surface of the land rises from near tide level along the Chester River to elevations exceeding 60 feet. The surface is gently rolling and quite generally forested. The higher elevations consist of low, rounded hills and hummocks of sandy soil, interspersed with hollows which are usually swampy, and contain accumulations of partially decayed organic matter mixed with silt.

Along the shore of Chester River the lower-lying land is quite generally sandy from near the water's edge up to 20 feet elevation. In the foreland region of Kent County, beginning near Chestertown, there are found detached and scattered areas of this sandy soil, often comprising 2 or 3 square miles each. From Rock Hall southward to Eastern Neck Island this soil is also predominant, though composed

of slightly finer-grained material than elsewhere in the county. Near Worton Point and on the extreme end of Still Pond Neck this soil is again present in its coarser phase. Other smaller areas of Norfolk sand are found over the upland, while the outcrop of the sandy underlying strata of Cretaceous, Eocene, and even of Pleistocene age, in the deep stream cuts along the Sassafras River, gives rise to small areas of Norfolk sand. The areas of this soil found along the forelands are usually slightly rolling or nearly flat, while those along the stream cuts are frequently very steeply inclined and consequently of little agricultural value.

The original sources of the sands entering into the composition of the Norfolk sand vary in different parts of the county. The greensands of Cretaceous and Eocene age consist of rounded quartz grains, glauconite, and some silt and clay. The weathering of outcrops of this material gives a sandy soil, usually found only along very deep stream cuts. This same material when reworked by streams and waves, transported to new localities and redeposited as a later sediment, forms a soil which has the same agricultural values as along the weathered outcrops. In some instances it is possible to secure materials along the present shores from Cretaceous or Eocene outcrops, from the Pleistocene sandy stratum, and on the surface of the new foreland terraces, which differ from one another chiefly in the amount of the glauconite still present. Texturally, they vary but slightly. Owing to this fact, areas due to all these different causes have similar crop values and are included in the same soil type.

The soil of the Norfolk sand consists of a medium to rather coarse sand, with gravel also occurring in some areas. The soil is usually brown or reddish-brown from the admixture of organic matter. It has a depth of about 9 inches. The subsoil also consists of a medium sand, generally red or yellow, frequently containing sufficient silt and clay to make it slightly adhesive. The steeper sloping areas of Norfolk sand have not been entirely cleared, and they are usually marked by a growth of chestnut and oak. The chestnut is found growing on this soil more frequently than on any other.

Norfolk sand is a typical truck soil, although not actually used for such crops to any great extent in Kent County. Near Chestertown and near Worton Point truck and small fruits are being cultivated on this soil, but it is usually farmed to the regular rotation used in the county. The excellent facilities for transportation and the proximity of several large cities should lead to a more pronounced specialization of crops in this region, and the Norfolk sand areas should be utilized as the best truck soil existing in Kent County.

The following analyses show the texture of three samples of Norfolk sand. While all are sandy soils, it is noticeable that the sample from Eastern Neck Island is of a finer texture than the other two samples.

Mechanical analyses of Norfolk sand.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5201	2 miles SW. of Chestertown.	Coarse brown sand, 0 to 8 inches.	1.37	2.66	26.76	27.90	17.37	7.89	12.77	3.03
5205	Eastern Neck Island.	Fine brown sand, 0 to 8 inches.	1.53	Tr.	1.97	3.70	39.27	36.60	13.80	2.79
5209	1¼ miles SE. of Millington.	Coarse brown sandy loam, 0 to 10 inches.	1.72	6.39	21.46	17.81	20.02	8.93	19.09	3.87
5202	Subsoil of 5201	Coarse yellow sand, 8 to 40 inches.	1.04	3.30	26.65	20.86	16.38	8.26	17.90	6.44
5206	Subsoil of 5205	Orange sand, 8 to 40 inches.	1.36	Tr.	2.80	5.50	42.85	26.46	14.70	5.74
5210	Subsoil of 5209	Coarse red sandy loam, 10 to 40 inches.	1.30	5.10	25.04	19.13	18.13	6.40	17.91	6.69

ELKTON CLAY.

Elkton clay occupies a total area of over 25 square miles (16,000 acres) in the foreland portion of Kent County. It usually lies between 15 and 40 feet elevation and its surface is nearly level, or at most only gently sloping. The larger areas of the Elkton clay are found along the bay shore and on the necks which extend out into the Chester River. Only small areas of this type occur eastward from Chestertown, in the southern part of the county, and it is only represented by a single area on the Sassafras River, just east of Shell Cross Wharf.

The materials forming this soil were deposited as a marine sediment during the latest stage of the Pleistocene, and they have since been elevated to their present position above tide water. The low foreland area is largely made up of the same material, but all of it has not proceeded to the same stage of soil formation. It will be noticed with respect to the Elkton clays in Kent County that all the areas lie in positions favorable to natural drainage, that is, they have the advantage either of considerable elevation above tide water or else of so lying that the slopes to natural drainage ways are short and steep. It is due to this position and to the progress of natural underdrainage that most of these areas have been naturally brought to a more productive state than the surrounding meadow lands.

The first processes of soil formation, when any area of sediment becomes a part of the land, are those of drainage and of weathering. The rainfall must be disposed of, and where the slope is sufficient stream ways are formed which dispose of the surface waters. If the material is not too impervious a large part of the rain water percolates through it and finds an underground outlet to main drainage ways.

The water passing underground carries various acids in solution, and these aid in soil preparation. The circulation of air also goes on unless the soil pores are filled with water. When air and water circulation is freely established various chemical and mechanical changes prepare the soil for crop production; but if they are interfered with these changes progress more slowly and the soil is considered wet, cold, and sour.

The materials constituting meadow areas and those of Elkton clay are frequently the same, but the natural processes of soil formation have proceeded much farther in the latter case than in the former.

Elkton clay is a yellow to brown silty loam soil, extending to a depth of about 9 inches. This is underlaid by from 12 to 30 inches of mottled gray and yellow clay loam, which grades imperceptibly downward into a heavy, dense, drab clay. The drab clay was the original form of this material, but the circulation of air and water and of the solutions of various chemical compounds in the water has changed the upper portion of the clay, while surface cultivation has changed the structure of the soil proper and mingled with it various amounts of organic matter.

The yellowing and mottling of the subsoil are due to the oxidation and deposition of iron salts held in the soil water, and this process is still in progress. It has made the heavy, plastic clay more loose and friable, and this aids the underground circulation of soil water.

The growth, death, and decay of organic matter on the surface of the soil and the incorporation of this organic matter with the soil not only furnish valuable plant foods, but also furnish a temporary mulch for the retention of moisture within reach of growing plants and additional organic acids for the further preparation of the deep subsoils.

The natural growth over a large part of the Elkton clay included white-oak, pitch-pine, and sweet-gum trees, and some areas still retain this growth. Other areas have been cleared only in recent years and are not yet fully prepared for their best work in crop production.

Elkton clay is more typically wheat and grass land than any other soil type in the county. The soil and subsoil are sufficiently retentive of moisture to enable grain crops to maintain a steady growth, except during extremely dry seasons. The chief difficulty attending the cultivation of this soil is its tendency to form into clods and lumps.

Wheat crops of from 30 to 35 bushels per acre are reported from different farms located on this soil type, and good grass crops can be obtained. The hay is apt to be rather coarse and of medium grade only, but this is due fully as much to impure seed and lack of proper care as to any property of the soil.

Stock raising should be undertaken more extensively on this soil than it has been, and use of stable manures and lime may be profit-

ably increased. Artificial underdrainage should be undertaken over considerable areas of the Elkton clay in order to facilitate the natural processes already under way.

The texture of this type is shown by the following analyses:

Mechanical analyses of Elkton clay.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5211	One-fourth mile NW. of Pomona.	Heavy yellow loam, 0 to 9 inches.	3.32	0.40	0.73	0.92	1.56	14.70	63.34	14.35
5213	3 miles NW. of Rock Hall.	Brown loam, 0 to 9 inches.	2.89	Tr.	.82	1.14	2.23	18.25	65.49	9.21
5212	Subsoil of 5211	Mottled clay loam 9 to 40 inches.	2.78	0	Tr.	.77	.90	17.96	60.90	16.66
5214	Subsoil of 5213	....do	2.54	0	Tr.	1.06	1.92	27.51	51.14	15.59

MEADOW.

The meadow land in Kent County comprises areas of flat, poorly drained land, best adapted to the production of grass or for pasturage. The meadows are not confined to soils of any one texture, but are dependent for their characteristics rather on physiographic than on textural features.

The stream valleys are usually wet, poorly adapted to ordinary tillage, and are of greater value for grazing than for any other purpose. Certain parts of the upland portion of the county are so situated that the natural stream drainage has proved inadequate to prepare them fully for cultivation, and they remain as forest areas. About 1 mile west of Massey an area of nearly 3 square miles still retains its meadow condition, owing to a lack of drainage, though the texture of the soil differs very little from the surrounding Sassafras loam. Two similar areas occur east of Chesterville, the northern one being above 60 feet in elevation and corresponding in texture to the Sassafras loam, the lower area sloping from 60 to 20 feet and resembling more nearly the Elkton clay. All three of these areas are so situated as to be capable of easy reclamation by artificial drainage.

The lower lying portions of the southeastern part of Kent County are also rather wet and fall within the meadow type, though a very little attention to drainage would fit them for the production of celery, cabbage, cauliflower, and late truck crops.

By far the largest meadow areas are found in the lowland division of the county, these areas usually lying between sea level and an elevation of 20 feet. They owe their present condition chiefly to lack of drainage.

The foreland portion of Kent County is the youngest part geologically, and drainage systems are not yet completely established. As a result, those areas which lie near water level are saturated nearly to the surface, and the meadow condition is the only one possible.

The natural growth on all of the meadow areas consists of willow oak, sweet gum, and other water-loving forms. The main forest areas of the county are found on the meadow areas, though they are not all of them forested. Recent removals of forests have thrown some of the foreland areas into cultivation, and wheat and grass are produced to fair advantage. The production of corn is not successful, for in wet seasons planting is usually prevented until late, on account of the water-soaked condition of the ground, and in time of drought the surface bakes to such an extent that growth is interfered with, and the crop becomes yellow and backward. This yellowing is known locally as "Frenching." Underdrainage, in order to permit better circulation of the air, and frequent shallow surface cultivation, in order to form a soil mulch, would help to prevent this baking.

The soil of the lowland meadows consists of a gray loam, having a depth of about 8 inches. The subsoil is a blue or gray clay loam which is very heavy and plastic when wet, but on exposure to the air usually bakes to a hard surface. The clayey subsoil contains considerable silt.

The meadow lands of Kent County may be reclaimed by underdrainage, and thus be added to the grain producing areas of the county. The upland meadows are so situated that drainage ditches may be cut to the heads of existing streams with laterals ramifying over the areas. Then local underdrains should be provided for each field. The only question involved is that of the comparison of the expense with the results to be obtained. The lowland meadows in some cases lie too near tide level to be reclaimed easily, but many of the areas now grown up to sweet gum and willow oak could be made to produce wheat and grass if properly drained.

The following analyses of meadow soil is directly comparable with the sandier phase of Sassafras loam, and underdrainage should increase its value and productiveness:

Mechanical analyses of meadow.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5217	1¼ miles NE of Chesterville.	Heavy yellow loam, 0 to 9 inches.	2.97	2.78	8.56	5.35	6.99	14.30	47.15	11.95
5218	Subsoil of 5217	Yellow clay loam, 9 to 40 inches.	2.59	2.37	8.17	5.96	7.37	9.85	46.83	17.16

SWAMP.

Swamp lands of Kent County fall into two classes—salt marshes and fresh-water marshes. The salt marshes occupy positions along the estuaries, and are subject to inundation by the highest tides, while the fresh-water marshes are usually formed along the upland streams, where the slope is insufficient to carry off all the surface water. The salt marshes comprise by far the larger area. Neither type is at present of any great agricultural value. When the value of lands in the East becomes greater, the tide can be excluded from the swamp marshes by diking, while artificial drainage will obliterate the fresh-water marshes, but so much other land remains in the East, either in forest or in a low state of cultivation, that the marsh areas are apt to play but a small part in agricultural operations for many years to come.

CONDITIONS OF AGRICULTURE.

Kent County has been an agricultural community from the time of its early settlement to the present day. In earlier times the county was divided into large manorial estates and later subdivided into smaller farms. Some of the farms have remained in the possession of single families for two hundred years. The effect of this long tenure is evident in the general prevalence of substantial farm buildings and in the high state of cultivation to which a very large proportion of the land has been brought. Substantial houses are found in all parts of the county, each forming the center of a group of farm buildings. The boundary lines and roads are marked by osage hedges, and long avenues of trees leading from the main highway to the residences are frequently found. The crops of early times were largely confined to the grains, while within recent years the cultivation of truck and canning crops has been introduced. The greatest recent change, however, began with the rise of the peach industry. Thousands of acres were devoted to peach orchards, and a full crop and fair prices brought excellent returns. For many years the peach crop was maintained, but the opening of new areas to the cultivation of the fruit affected the markets, and as the orchards grew older they became more subject to various diseases, in spite of every care, and at present the acreage devoted to peaches is decreasing rather than increasing. The Kieffer pear has been introduced along with other varieties and proves a wonderful producer. The pears are sold to local canning companies at prices varying from 8 to 25 cents per bushel, and even at the lowest price some profit is derived. Tomatoes are raised extensively as a canning crop and usually yield fair returns. Asparagus beds are found on many farms, and small fruits are being cultivated to a limited extent. The areas of Norfolk sand found in the county are well adapted to the production of truck and

small fruits, such as strawberries, raspberries, blackberries, currants, and grapes.

Dairying, stock raising, and sheep raising are other farm industries of the county. Several creameries manufacture butter. The dairy industry should be made to supplement the canning industry. Sweet corn can be produced in Kent County for canning purposes, rendering a cash return of from $18 to $25 per acre for the green ears. The forage crop remains and may be cured and stored for dry feeding or, better, may be shredded and stored in silos for green feeding. The advantage to be derived from the cash return from the canning factory and the creamery is not the only benefit obtained from this practice. The item of farm expense annually charged to the fertilizer bill may be very largely eliminated by the production of increased amounts of stable manure. Moreover the item of transportation charges is also reduced. The nearness of such markets for dairy products as are furnished by Washington, Baltimore, and Philadelphia should awaken the community to the desirability of increased dairying along the most modern lines of development

TRANSPORTATION.

Kent County is well situated with respect to transportation facilities, both for internal communication and for egress to the centers of commerce and trade along the Atlantic seaboard.

The county is bounded by over 80 miles of coast line. The head of navigation on both the Sassafras and Chester rivers is not reached until near the Delaware line, and the entire western limit of the county is formed by Chesapeake Bay.

Five or six steamboat lines carry freight and passengers to Baltimore and Philadelphia, and during the grain and fruit seasons extra freight steamers are provided. Ice only interferes with navigation during periods of excessive cold. In addition to the opportunities for navigation two railroads cross the county, one having its terminals at Chestertown and at Clayton, Delaware, while the other connects Centerville, Queen Anne County, with the trunk lines farther north, entering Kent County at Millington and crossing the Delaware line at Golts. The railroads cross each other at Massey, and together furnish rail communication with trunk lines.

Kent County, having no elevations above 110 feet and no steep grades except near the largest streams, should possess one of the finest highway systems in the State, for, while the consolidated rocks necessary for the building of macadam roads are not found in Kent County, large supplies of suitable rock exist within easy transportation distance, or other materials found in the county may be used. The gravels of Kent County are in some cases highly indurated by iron cement, and when in this condition can be packed to form a fair

road surface. The present system of road construction, judged by its results, might be considerably improved without increasing the money expenditure. The necessity for good drainage and grading does not seem to be fully understood, nor are the known sources of gravel supply for road surfacing used. The art of rolling a road surface into a compact mass also seems to be unknown. Aside from the advantages of soil and climate no interest is so vital to an agricultural community as a good transportation system, and good highways form an essential part of the system.

CLIMATE.

The following table, compiled from the Maryland Weather Service, Vol. I, presents the summaries of climatological observations taken at Chestertown. The blanks represent months for which the record has not been kept during the five years necessary to establish reliable means.

Climatological data for Chestertown.

Month.	Mean monthly and annual temperature.	Mean maximum temperature.	Greatest departure above.	Greatest departure below.	Mean minimum temperature.	Greatest departure above.	Greatest departure below.	Mean daily range.	Highest recorded temperature.	Lowest recorded temperature.	Mean monthly and annual precipitation.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	Ins.
January	32	39	+4	−2	26	+5	−3	13	63	5	2.9
February	33	39	+3	−7	25	+4	−9	14	61	− 9	2.6
March	42								79	16	3.3
April	51								87	25	4.0
May	63	73	+5	−3	54	+4	−2	19	92	37	4.7
June	71	81	+2	−4	61	+2	−2	20	94	43	3.9
July	76	84	+2	−3	67	+2		17	97	54	3.5
August	74								93	51	5.4
September	70								90	41	3.4
October	55	63	+3	−2	47	+4	−6	16	83	30	3.0
November	46	52	+4	−4	38	+4	−3	14	75	22	3.3
December	36	43	+2	−2	29	+3	−3	14	65	9	2.7
Annual	54								97	− 9	42.6

SOIL SURVEY FROM RALEIGH TO NEWBERN, N. C.

By WILLIAM G. SMITH.

INTRODUCTION.

The area mapped extends from Raleigh to Newbern, along the line of the Southern and the Atlantic and North Carolina railways, a distance of 105 miles, about 9 miles wide, and contains approximately 1,000 square miles, or 640,000 acres. (See fig. 18.)

The State department of agriculture paid all the field expenses of the survey party, as well as all expenses incident to the making of a good base map showing wagon roads, railroads, houses, towns, and streams, and proposes to follow up the survey and locate test farms on the more important soil types revealed by the soil survey, the object being to study further the fertilizer problems as well as the cultural methods and crops adapted to the different soil types. Two

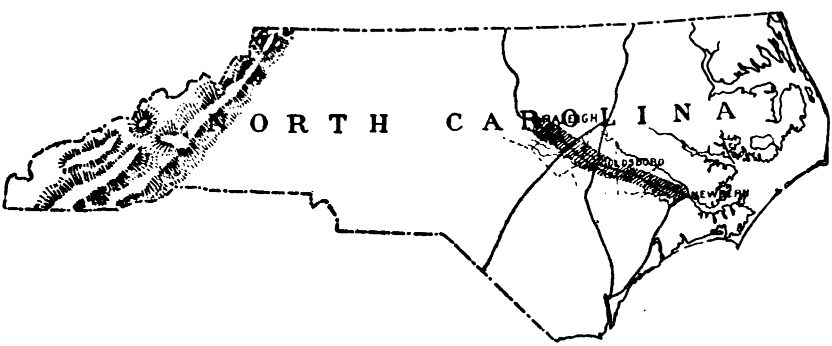


FIG. 18.—Sketch map of North Carolina, showing area surveyed.

test farms are already located, one at Tarboro, in Edgecombe County, and the other at Red Springs, in Robeson County. The farm at Tarboro was visited by the survey party and its soil correlated with a similar soil type of the area surveyed.

Credit is due the State geological survey for aid furnished through the State Department of Agriculture in securing competent traverse men to make the base map.

TOPOGRAPHY.

From Raleigh to Newbern there is a gradual change from the rolling uplands of the Piedmont Plateau to the low, level country of the Coastal Plain region. Raleigh is situated near the eastern edge of

the Piedmont Plateau, so the greater portion of the area surveyed lies within the Coastal Plain.

The Piedmont Plateau extends about 25 miles east of Raleigh, and is characterized by rough, hilly country, with narrow stream valleys in which the streams have considerable fall. The greatest development of the Piedmont Plateau lies west of Raleigh, extending to the foot of the mountains. In the vicinity of Raleigh the elevation above sea level is about 300 feet, and a few miles southeast, at Garner Station, on the Southern Railroad, the elevation is 383 feet. From Garner eastward there is a fall of about 7 feet per mile to Selma, where the elevation is 175 feet and where all trace of the plateau region is lost and the flat or gently rolling Coastal Plain area proper begins. The fall from Selma to Newbern, which has an elevation of 16 feet, averages about 2 feet per mile. From Selma to Newbern the country is generally low and flat and in the eastern portion are swamps. The largest swamp is located about Dover and is known as the Dover Pocoson, while the next largest is near Newbern. They are depressions of from 2 to 10 feet below the surrounding, generally flat land, and represent about 200 square miles in extent. The elevation at Dover is 65 feet, making an average of less than 2 feet fall eastward to Newbern.

The streams possess but few branches, are generally in deeply cut beds with abrupt banks, slow flowing, and subject to several feet rise during heavy rainfall. The Neuse River, the largest occurring in the present survey, is navigable as far as Smithfield except when the water is excessively low.

CLIMATE.

The following table[1] shows the mean monthly temperatures and rainfall during the growing seasons at three stations in the area surveyed. The figures are normals made up from seventeen to twenty-seven years' records.

Mean monthly temperature and rainfall.

Month.	Raleigh.		Goldsboro.		Newbern.	
	Temperature.	Rainfall.	Temperature.	Rainfall.	Temperature.	Rainfall.
	° F.	° F.	° F.	° F.	° F.	Inches.
April	59.1	3.22	60.6	4.76	59.6	3.72
May	68.2	5.45	69.6	4.99	68.4	4.44
June	75.7	4.32	77.2	5.18	75.9	4.75
July	78.0	6.44	79.8	6.08	78.9	7.07
August	76.4	6.24	78.3	7.27	77.3	8.08
September	71.1	3.22	72.8	4.80	72.9	5.45
Annual	59.6	50.21	61.5	53.56	61.3	56.08

[1] Climatic Conditions Affecting Water Power in North Carolina, 1899, by C. F. Von Herrmann.

The average temperature and rainfall for the Coastal Plain section for the seasons are as follows:

Average seasonal temperature and rainfall.

Season.	Temperature.	Rainfall.
	° *F.*	*Inches.*
Spring	59	12.85
Summer	77	17.04
Autumn	62	13.10
Winter	45	12.24
Year	60.8	55.23

CONDITIONS OF AGRICULTURE.

From Raleigh eastward to Newbern there is a gradual increase in the size of the farms. In the hilly regions east of Raleigh the farms contain about 110 acres; in the middle portion of the area surveyed the farms contain on an average about 140 acres, while in the level country about Newbern there are many large plantations of more than 1,000 acres, and the average farm contains 225 acres.

The improvements on these farms vary greatly in the different sections of the area. Usually they possess a dwelling house, barns for stable purposes, and wagon sheds, and in the tobacco area curing sheds are always found. The tenant houses for the colored laborers form a part of the farm equipment, especially on the larger plantations. Fences are maintained at a minimum expense, for the stock laws in most of the counties are such that protection against stray cattle and other stock is unnecessary.

There are several systems of cultivating the farms. Where the farms are small they are usually farmed by their owners, but where they are larger the owners may manage the entire farm and employ labor necessary to carry on the operation. Again, portions of the farm may be rented for a cash rent or on the share system. A favorite system is to rent portions of a large farm to a tenant on shares provided he buys his provisions, etc., from the plantation owner, who conducts a large general store. In the entire area the labor is both white and colored, and frequently both kinds are employed on the larger farms. For such crops as cotton and tobacco, the negro labor is as capable as white labor. Fig. 19 shows a typical cabin of a negro family in this section.

As the area surveyed follows so closely the railroad throughout the entire distance, transportation by rail is very good, and some of the industries, as, for example, the trucking industry, have been made possible by the advantage which comes from rapid transportation. In the eastern part of the area water transportation is available and has been utilized to a considerable extent in developing the resources

of the country. The wagon roads of the area are not good. While some of the roads have been constructed at considerable expense and can be easily traveled, by far the larger number of roads have received no attention whatever, and are consequently in poor condition for either light or heavy hauling.

The principal crops are corn, cotton, tobacco, and truck. Corn has always been one of the staple crops of the entire area and occupies a prominent place in the various crop rotations used in the different sections of the area. Cotton is also one of the important crops grown, and the yield per acre shows the beneficial results of improved methods of culture and of the attention given to fertilizers. The effort is

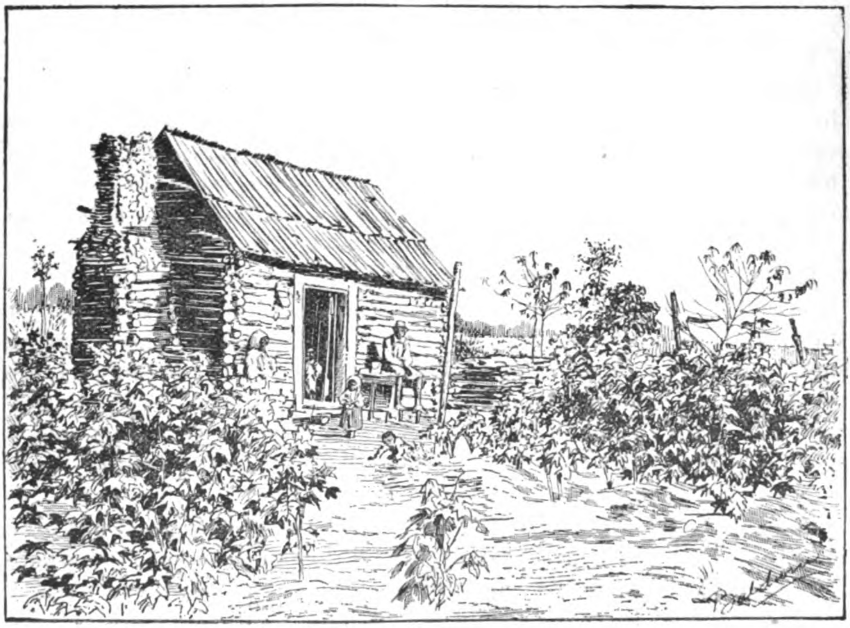
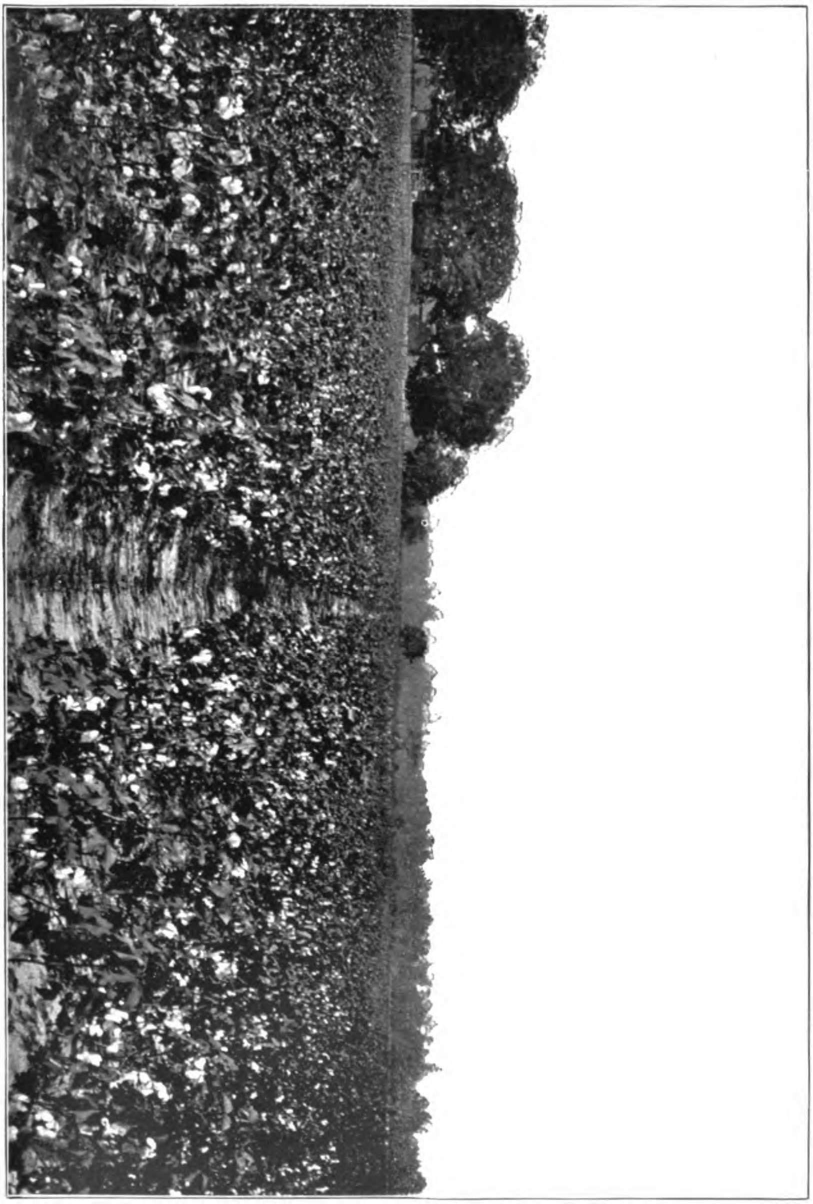


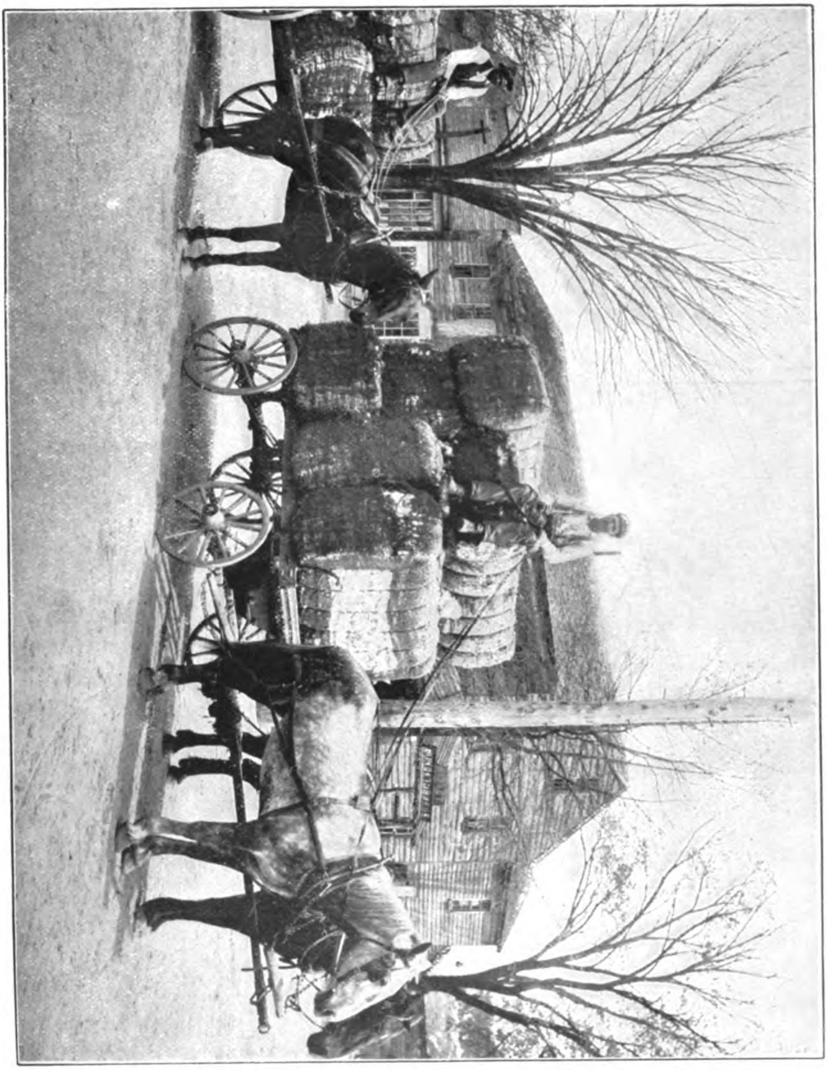
FIG. 19.—Typical negro cabin.

being made to manufacture the crop where it is grown, and in this way an important industry is being developed which has a far-reaching influence on the economic development of the State.

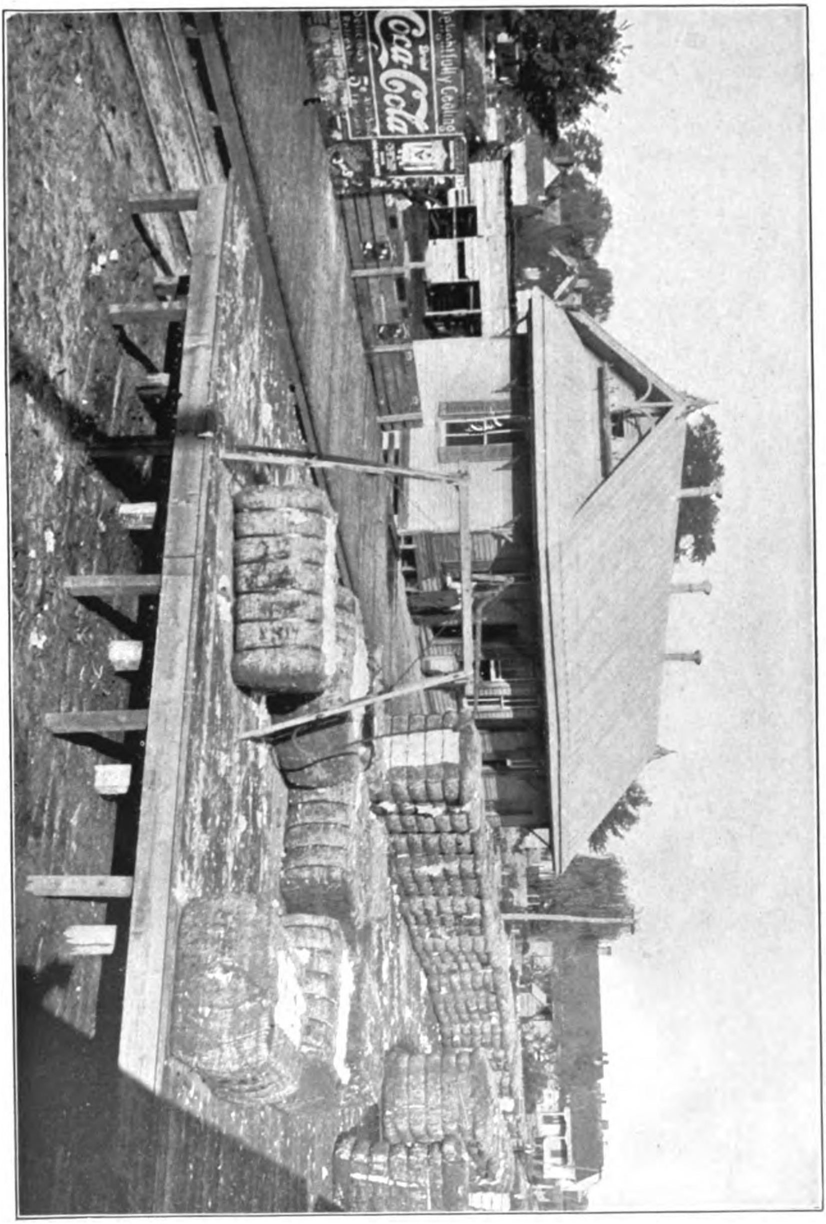
Since the introduction of bright tobacco in the eastern part of the State it has achieved remarkable success, and large districts of the area surveyed produce a fine type of lemon-yellow tobacco. In addition to the crops grown the development of the truck industry in the eastern portion of the area has made valuable large tracts of land which were formerly not desirable for agricultural purposes. Nearly all classes of early truck and early fruits are grown, and handsome profits are realized by successful farmers. The largest shipments of truck are from Goldsboro, Newbern, Kinston, and Lagrange.



COTTON FIELD.



HAULING COTTON TO MARKET.



COTTON PLATFORM AT KINSTON.

SOILS.

CECIL CLAY.

The Cecil clay is a red clay soil, with sharp quartz sand intermixed, 6 inches deep, containing from 10 to 30 per cent of quartz and rock fragments in both soil and subsoil. It is underlaid by a tenacious red clay subsoil, which is reached by ordinary plowing. This soil is locally known as "red clay land."

The soil is derived from the decomposition of granite, gneiss, and other crystalline rocks. The quartz fragments are derived from the quartz intrusions of the original rocks. While the presence of these fragments makes the soil and subsoil more friable and facilitates drainage, they obstruct plowing a great deal and are wearing on all soil implements.

The red clay subsoil possesses a peculiar coherency sufficient to make well curbing unnecessary; yet it is sufficiently porous to absorb rainfall and to allow a steady percolation of water through it into wells and streams. The red clay subsoil of the Cecil clay is very important, as it forms also the subsoil of sandy deposits in the Raleigh and Durham areas.

It is a fertile soil, well suited to cotton, grain, and grass. The yield of cotton ranges from three-fourths of a bale to 1 bale per acre, depending on the cultural methods employed.

The following table shows the mechanical analyses of the upper 6 inches and the underlying tenacious red clay subsoil. While distinctively a clay soil, the surface shows an infusion of sand that makes it more friable than the material beneath, which has nearly double the amount of clay possessed by the surface soil. It must be borne in mind that the quartz and rock fragments, which are not included in the table and vary from one-half inch to 4 inches in diameter, tend also to make the soil more friable. They vary in amounts from 10 to 30 per cent.

Mechanical analyses of Cecil clay.

[Fine earth.]

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5219	2 miles S. of Raleigh	Dull red sandy clay loam, 0 to 6 inches.	6.34	9.10	10.89	7.48	14.61	6.85	21.37	22.42
5220	Subsoil of 5219......	Stiff red clay, 6 to 36 inches.	8.03	6.04	7.88	4.78	8.68	4.59	19.90	39.80

CECIL SANDY LOAM.

Cecil sandy loam is a brown sandy loam soil from 6 to 10 inches deep, containing from 10 to 30 per cent of quartz and rock fragments. It is underlaid by a red clay, containing quartz and rock fragments similar to the subsoil of the Cecil clay. It is locally known as "brown land."

Cecil sandy loam differs from Cecil clay in possessing a much larger percentage of sand in the soil. It is more friable than Cecil clay and more easily tilled, though the quartz and rock fragments have a wearing effect on plows and other soil implements.

This type of soil is found in large areas in the vicinity of Raleigh and in smaller areas at Clayton and Wilsons Mills. There are some large and gently rolling fields of this soil, but generally it is quite hilly.

Cotton, small grain, and corn do well on this soil, the cotton production averaging from one-half to three-fourths of a bale per acre where fertilizer is used. Bright tobacco is grown to some extent on this soil. Because of the moist, retentive character of the subsoil this type of soil withstands drought quite well. The forest growth is like that common to the plateau section, differing from the Coastal Plain forest growth in that it possesses a larger proportion of hardwood than pine.

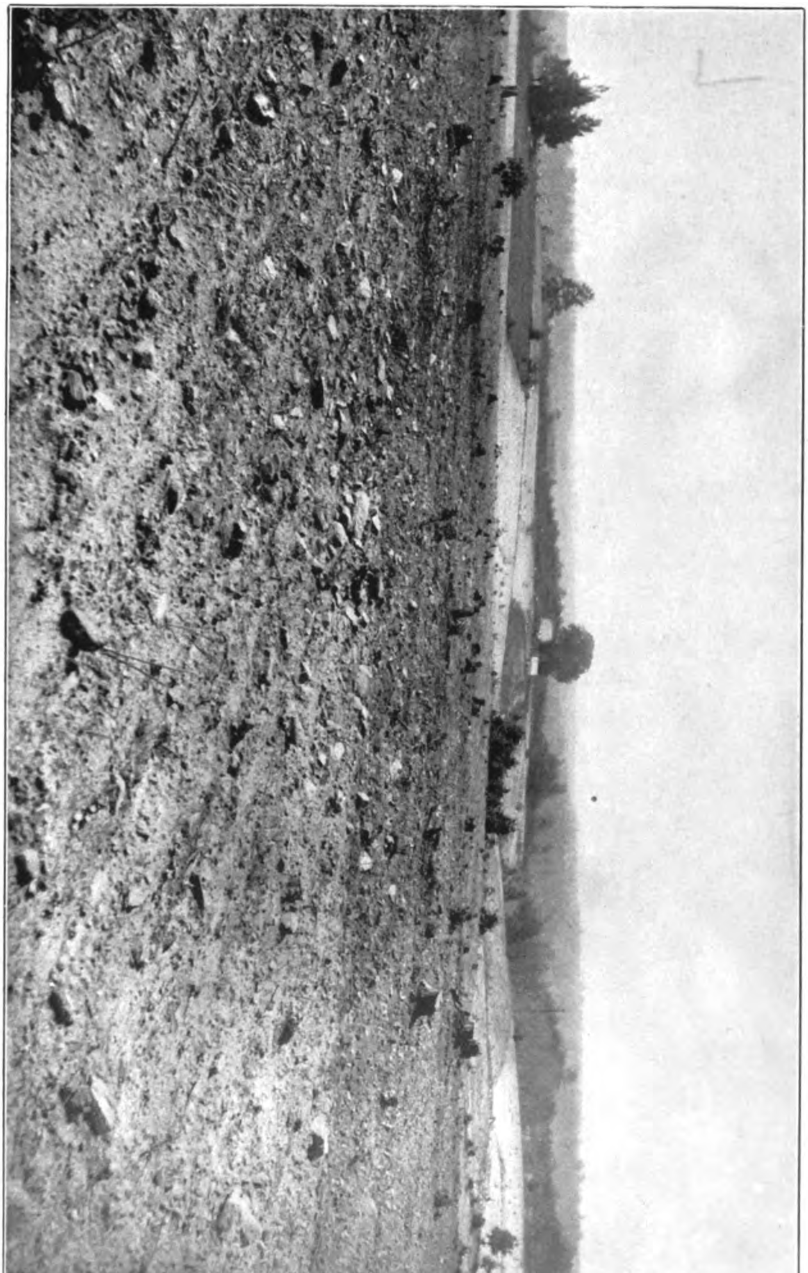
The following mechanical analyses of the soil and subsoil of the Cecil sandy loam show a large and uniformly proportioned infusion of sand in the soil, while the red clay subsoil analysis is almost indentical with that of the Cecil clay subsoil:

Mechanical analyses of Cecil sandy loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5223	2¼ miles S. of Raleigh.	Brown sandy loam, 6 to 10 inches.	3.58	6.03	18.14	12.76	26.73	10.49	12.20	9.35
5224	Subsoil of 5223	Stiff red clay, 16 to 30 inches.	7.63	4.94	8.40	5.77	11.36	3.94	19.37	37.92

DURHAM SANDY LOAM.

Durham sandy loam consists of a gray, rather coarse sandy soil from 12 to 15 inches deep, generally overlying a yellow clay subsoil. Like the two preceding types, quartz and rock fragments are found to the extent of from 10 to 30 per cent in both soil and subsoil. The



CECIL SANDY LOAM.

quartz and rock fragments seem to have been derived from the Piedmont formation, since the Durham sandy loam is always found in or close to the plateau area. The soil is easily tilled except for the presence of the fragments, which have the same wearing effect on soil implements noted in the two preceding types.

The origin of the subsoil is in part sedimentary, as is shown by the occasional presence of gravel and in part residual.

The largest development of Durham sandy loam is found south of Raleigh, and from here on to its eastern limit it occurs in small and irregular patches. Like the two preceding soils it ceases to appear beyond Wilsons Mills in the area surveyed. It also partakes of the hilly surface characteristic of the Piedmont Plateau.

The Durham sandy loam is better adapted to corn, bright tobacco, and truck than it is to cotton or small grain. However, with sufficient application of fertilizers, about one-half of a bale of cotton per acre may be grown. Because of its sandy character and low per cent of clay, this soil is more subject to leaching and drought than the preceding soils.

The following mechanical analyses show a larger proportion of sand and less of clay in both soil and subsoil than are found in the preceding types. It may be mentioned in passing that the analysis of the soil of the Durham sandy loam would not suggest the marked difference between it and the Cecil sandy loam that is evident in the field. The former is rather loose and leachy, while the latter is moist, retentive, and spongy, because of the slightly larger proportion of clay.

Mechanical analyses of Durham sandy loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5225	3¼ miles S. of Raleigh.	Gray stony sandy loam, 12 to 15 inches deep.	3.12	7.33	12.21	11.22	33.30	13.70	12.86	5.51
5226	Subsoil of 5225	Yellow or red clay, stony, 12 to 36 inches.	6.51	3.92	8.74	6.69	18.88	6.44	23.96	24.00

NORFOLK SANDY SOIL.

The Norfolk sandy loam varies from a coarse, sharp, gray, sandy soil to a gray, sandy loam, 10 to 20 inches deep, overlying a yellow clay. It is sedimentary in origin. No rock or quartz fragments are present in either the soil or subsoil, but occasionally gravel is found

in the subsoil. The soil is easily tilled, the natural drainage is good, and, because of the clay subsoil, it withstands drought fairly well. It is found to a large extent east and south of Raleigh, as well as in the vicinity of Clayton and Wilsons Mills and to the north of Princeton.

The surface of the Norfolk sandy soil is more level and the areas larger and more uniform than any of the preceding soils, yet when it occurs near streams it is hilly. About 5 miles north of Clayton, along the Neuse River, this soil occurs as a rather thin deposit (4 to 8 inches), which is eroded in places, exposing the yellow clay subsoil. In this locality when the plow strikes the subsoil, a soil of a somewhat heavier character is formed.

This soil is well suited to bright tobacco, corn, and truck, and to some extent to cotton.

The following analyses show some striking resemblances in the proportion of sand, silt, and clay to that of the Durham sandy loam, but since it contains no rock fragments or gravel it has a field characteristic quite different from any of the preceding soils. The lower percentage of organic matter (only 1 per cent, as against 3 per cent in the preceding soils) accounts for the gray, bleached appearance that marks this soil in the field as compared with the dull color of the other types.

Mechanical analyses of Norfolk sandy soil.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5229	4 miles S. of Raleigh	Gray sandy loam, 0 to 15 inches.	0.76	8.56	22.23	12.13	33.73	10.88	9.98	3.30
5230	Subsoil of 5229......	Stiff, yellow clay, 15 to 36 inches.	4.68	8.90	12.38	5.39	15.10	8.06	15.67	29.81
5231	4 miles N. of Princeton.	Gray sandy loam, 0 to 15 inches.	1.18	2.74	27.22	20.28	24.18	9.40	10.12	4.88

SUSQUEHANNA GRAVEL.

Susquehanna gravel is a deposit of gray sandy soil from 12 to 15 inches deep, overlying a yellow clay subsoil. From 10 to 25 per cent of gravel of a diameter of from one-fourth of an inch to 2 inches is found in the soil and often a like amount is also found in the subsoil. If the gravel were eliminated this soil type would be identical with the Norfolk sandy soil, which it resembles in possessing a sharp, bleached-looking sand as well as having a similar sedimentary origin. The gravel in some places obstructs tillage very much, and is quite wearing on soil implements.

The crops suited to this soil are the same as are adapted to the Norfolk sandy soil—bright tobacco, corn, and truck and cotton to some extent. This soil is slightly given to leaching, but because of the clay subsoil it holds fertilizers and withstands drought quite well. The distribution of this soil is limited to a few small areas in the vicinity of Clayton and Auburn, amounting to about 3 square miles.

The following analysis of the fine earth portion of the Susquehanna gravel shows it to be similar in texture to the Norfolk sandy soil, the principal difference as before noted being the gravel content of from 10 to 25 per cent. No analysis of the yellow clay subsoil was deemed necessary, as it is so similar to the Norfolk sandy soil.

Mechanical analysis of Susquehanna gravel.

[Fine earth.]

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5233	10 miles S. of Raleigh.	Gray sandy soil, 0 to 15 inches.	1.57	12.70	17.76	12.02	26.17	15.22	9.64	4.73

GARNER STONY LOAM.

Garner stony loam is a sandy loam containing from 40 to 60 per cent of rock fragments and gravel. At a depth of from 6 to 15 inches it overlies a red tenaceous brick-clay subsoil, which often contains a trace of sand, rock fragments, and gravel. This type is found along streams and doubtless owes its origin to the extraction of clay and silt during a period of the rapid flow of the streams which it generally borders. It is found north of Clayton along the Neuse River and south along Crabtree Creek. This type packs firmly over the clay substratum, affording to all the roads that traverse it a firm roadbed almost equal to macadam.

Tillage is almost impossible, but in cases where cotton is once rooted good crops are secured because of the clay subsoil. These areas, however, are generally given to the growing of commercial pine and to cattle and hog pasture runs.

The following table shows the mechanical analyses of the soil and subsoil. The soil would be a good friable sandy loam were it not for the presence of the large amount of rock fragments and gravel that makes this soil almost useless for tillage purposes.

Mechanical analyses of Garner stony loam.

[Fine earth.]

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5234	3 miles S. of Clayton.	Stony, gravelly soil, 0 to 15 inches.	4.03	17.04	13.72	7.86	17.86	17.80	14.07	7.39
5235	Subsoil of 5234	Stiff yellow and red clay, 15 to 40 inches.	6.62	3.65	4.30	2.35	5.77	8.76	22.37	45.91

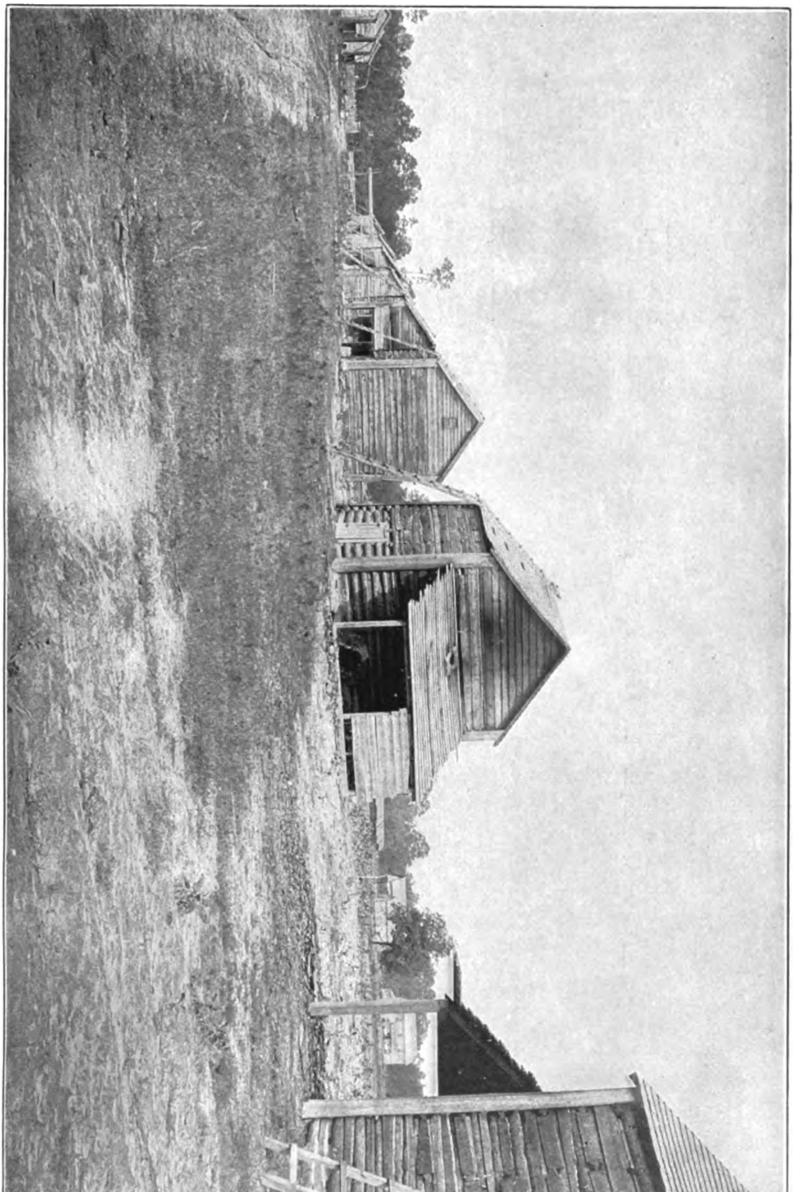
SELMA SILT LOAM.

This is a gray silty loam mixed with fine sand 18 inches deep, overlying a mottled yellow clay subsoil, which sometimes contains fine sand and small gravel. It is a large and important area, found in its greatest extent in the vicinity of Selma and Princeton and to a lesser extent about Goldsboro. The surface is gently rolling, the natural drainage is good, only a small portion possessing rather poor natural drainage; artificial drainage is possible in nearly all such cases.

The Selma silt loam area is characterized by numerous fine sandy knolls and ridges from 2 to 6 feet high and from 5 to 40 acres each in extent. With their silty clay subsoils at a depth of 18 inches these ridges and knolls are especially suited to the growing of bright tobacco, corn, or truck, while the lower-lying more silty portion is well suited to cotton, which it yields at the rate of from three-fourths of a bale to one bale per acre. Both the sandy knolls and the lower-lying portions, however, admit of being used for cotton, corn, tobacco, or truck, and are so used. Both phases of this type are choice soils, easily tilled, and respond well to fertilizers.

The clay subsoil, while possessing some sand and occasionally gravel the size of beans, is sufficiently coherent to make the use of well curbing unnecessary. Wells from 20 to 40 feet deep are commonly found here, as in the other areas discussed. There is, however, a movement toward the use of drive pumps, which furnish water freer from contamination. In this area a water-bearing sandy stratum underlying the yellow silty clay is reached by drive pumps at a depth of from 30 to 60 feet.

The forest growth consists largely of pine, oak, and gum. Several small wild fruits are found; while of the domestic fruits the peach and cider apple are common. Many domestic varieties of grapes, such as the Delaware, Concord, and Scuppernong are grown.



GROUP OF BRIGHT-TOBACCO BARNS WHERE TOBACCO IS CURED BY ARTIFICIAL HEAT.

BRIGHT TOBACCO BEING SOLD ON WAREHOUSE FLOOR AT GOLDSBORO.

The following table shows the analyses of the soil and subsoil of the Selma silt loam.

Mechanical analyses of Selma silt loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5237	1 mile W. of Princeton.	Gray silt loam, 0 to 18 inches.	1.52	8.72	23.92	12.82	26.62	11.90	18.25	3.72
5238	Subsoil of 5237.....	Mottled yellow clay with base of fine sand and gravel, 18 to 40 inches.	2.65	10.21	14.66	11.62	17.70	9.68	11.57	21.26

SELMA HEAVY SILT LOAM.

This is a rather heavy gray silty loam, from 10 to 20 inches deep, overlying a stiff mottled clay. It is often spoken of as "stiff land" or "clay land." Like the preceding soil, it is of sedimentary origin and represents a large and important area. It is found as large flat areas in the vicinity of Selma, Princeton, and to the north of Dover. There is no sharp line of demarcation between the soil and subsoil, one gradually merging into the other. The subsoil is, however, much stiffer than the soil.

The knolls and ridges spoken of in the preceding soil type very seldom occur in the Selma heavy silt loam. Natural drainage is poor; artificial drainage is possible and nearly always necessary to insure a good crop. Fertilizers are well retained. This soil is suited to cotton, which it yields at the rate of from three-fourths of a bale to little more than one bale per acre. Under good drainage conditions, however, corn, vegetables, and small fruits are successfully grown.

The following analyses of three soils and two subsoils show the heavier character of this soil as compared with the immediately preceding type. The marked difference between the soil and subsoil is in accord with the observations in the field. No. 5242, representing the heavier phase of this area, is locally known as "clay soil." Nos. 5240 and 5244 represent the area of largest extent.

Mechanical analyses of Selma heavy silt loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5240	2 miles NE. of Kinston.	Heavy gray silt loam, 0 to 10 inches.	3.82	2.01	4.16	4.40	37.80	21.40	22.29	4.26
5241	Subsoil of 5240	Stiff gray-mottled clay, 10 to 36 inches.	2.33	1.22	3.38	3.92	29.97	21.38	21.56	15.94
5242	3 miles N. of Tuscarora, near Jasper post office.	Stiff mottled gray clay loam, 0 to 10 inches.	2.16	1.74	4.76	5.30	35.84	9.49	23.04	17.30
5243	Subsoil of 5242	Stiff gray-mottled clay, 10 to 36 inches.	3.17	1.88	4.17	3.92	23.24	6.38	19.90	37.31
5244	One-fourth mile SW. of Selma.	Heavy gray silt loam, 0 to 8 inches.	1.86	.52	1.56	1.79	13.34	34.96	37.44	7.96
5245	Subsoil of 5244	Yellow silty clay, 8 to 36 inches.	3.14	6.38	11.02	8.62	21.44	11.48	11.39	26.46

GOLDSBORO COMPACT SANDY LOAM.

This is a soil type which comprises several variations in texture, all consisting, however, of gray, ashy, sharp, generally compact sand. Usually it has no distinctive subsoil, though it often grades gradually into a sandy clay substratum. It is a sedimentary soil varying in color from a bleached gray to black, the color being due to organic stains. This type is generally found in lower lying flat areas along the Neuse River at Kinston and extending into and around the Dover Pocoson area. The lower lying portions, containing the black sandy features, were once subjected to swamp conditions. When these are drained and an application of lime used, good crops of cotton and corn are secured.

The gray or bleached phase lies somewhat higher, but it generally requires considerable artificial drainage. In the gray phase occur compact spots from 5 to 20 acres or more in extent, which, on account of their compactness, suggest the possible presence of some cementing material. These spots are undesirable and are locally known as "stiff gray land," which when partially dry can scarcely be plowed. Instances are noted where a good application of barnyard manure seems to have made these compact or seemingly cemented areas more friable.

Cotton and corn are generally grown with fair success on all the variations of this soil type where drainage is practiced and suitable cultural methods are employed.

The following table of analyses is given to show the peculiar sandy-

clay character of both soils and subsoil. No. 5250 represents the coarse phase, while the other three (soils) represent the finer phase.

Mechanical analyses of Goldsboro compact sandy loam.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5246	2¼ miles E. of Cove post office.	Fine, gray, compact, sandy loam, 0 to 15 inches.	1.29	0.94	2.50	1.70	12.98	37.39	31.76	11.27
5247	Subsoil of 5246	Yellow-mottled clay with fine sand, 15 to 40 inches.	2.09	.68	1.74	1.18	9.92	26.35	31.57	26.20
5248	Three-fourths mile SW. of Kinston.	Fine, gray, compact, sandy loam, 0 to 20 inches.	3.76	11.22	17.18	15.30	18.94	5.90	10.19	16.80
5249	3 miles N. of Lagrange.	Gray, very compact loam, 0 to 16 inches.	1.38	7.26	14.46	11.14	20.56	14.22	19.25	10.77
5250	1 mile E. of Goldsboro.	Coarse, compact, sandy loam, 0 to 20 inches.	3.09	31.68	23.38	7.22	9.22	4.22	11.65	9.37

NORFOLK SAND.

The Norfolk sand is a deep sandy soil 3 to 6 feet or more in depth. Often the first 6 inches is gray or bleached in color, while the underlying portion is a brown or yellow sand of the same texture. In different localities it varies from a fine sandy soil to a coarse sandy soil, all the variations having, however, the same general character as regards the production of crops.

The Norfolk sand is an extensive and important type. It is a truck soil, suited to the early maturity of crops because of its warm, dry nature. It occurs to a large extent along the Neuse River at Lagrange, Kinston, and Newbern, and also in some places 2 or 3 miles from the river. Immediately south and southwest of Lagrange is found a large area of the coarse phase, at Newbern occurs the medium phase, and 3 miles south of Lagrange, bordering the Neuse River, is the fine sandy phase (soil 5251), on which cotton does well.

The surface of the Norfolk sand is generally flat or gently rolling, possessing good drainage. Occasionally spots are met which are often subject to drought because of the great depth to the water table.

The following table shows the mechanical analyses of two samples of the Norfolk sand:

Mechanical analyses of Norfolk sand.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5251	3 miles S. of Lagrange.	Fine sandy soil, 0 to 20 inches.	1.75	Tr.	1.84	8.90	72.86	8.95	2.43	2.52
5252	1¼ miles W. of Newbern.	Brown sandy soil, 0 to 40 inches.	.76	0.60	3.80	8.22	68.62	12.84	2.74	2.30

SANDHILL.

The Sandhill soil is a gray, sharp, incoherent sand of considerable depth—from 10 to 50 feet or more—found usually in the form of high flat ridges or hills. The first 6 or 9 inches is generally bleached, while the underlying portion is of a brown or reddish color and of the same texture as the soil. Its origin appears to have been a sand bar deposited by coastal waters and modified by wind action.

In the area surveyed only a small margin of this extensive Sandhill soil of the Coastal Plain occurs about 2 miles south of Goldsboro. It was sufficient, however, to correlate it with the great sand ridge that extends from about this point southward through North and South Carolina, Georgia, Alabama, Mississippi, Louisiana, and terminating in Texas.

It is a dry, barren soil, as it lacks sufficient moisture for crops. In wet seasons or when irrigated, truck does well. The natural growth is pine and scrub oaks. Stone fruits and small fruits, such as peaches, apples, grapes, and the blackberry, which are able to extend their roots deep, do well if they get started and are well cared for.

From the foot of the Sandhill type, even during dry seasons, a constant flow of pure water generally comes. The roads, as a matter of course, that traverse this soil are very loose and sandy, except in wet weather, when they are more easily traveled.

The following table of analyses shows a similarity of this type to the soil of the Norfolk sand, which is in keeping with the field observation as to texture and origin. The low per cent of organic matter and small clay content tallies also with the loose, leachy character of this soil noted in the field.

Mechanical analyses of Sandhill.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5255	2¼ miles SW. of Goldsboro.	Gray, loose, incoherent, sandy soil, 0 to 40 inches.	1.47	3.86	9.62	18.96	40.74	15.78	5.02	4.12
5256	3 miles W. of Goldsboro.	.....do............	1.78	2.16	32.22	28.30	23.90	4.66	4.06	2.75

NORFOLK FINE SANDY LOAM.

This type consists of a mellow, fine, sandy loam from 10 to 15 inches deep, overlying a yellow, rather stiff clay subsoil. The soil and subsoil are of sedimentary origin. This type represents a large and important area in the eastern part of North Carolina. In the present survey it occurs to a large extent at Kinston and from thereon to Newbern.

This soil is peculiarly adapted to a wide range of crops, being well suited to the growing of cotton, corn, truck, and bright tobacco. Cotton yields from one-half to three-fourths of a bale per acre. Fertilizers are retained and drought is withstood quite well because of the clay subsoil. Open wells 20 and 30 feet deep are quite common in this area; a water-bearing stratum of sand is reached by drive pumps at a depth of from 60 to 80 feet. The test farm at Tarboro, Edgecombe County, is located on this important soil type.

The following table of analyses shows the distinctive character of the Norfolk sandy soil, namely, a fine, rather mellow sandy soil underlaid with a rather stiff yellow-clay subsoil containing a trace of fine sand. No. 5253 represents a variation of this type where it grades into the Norfolk sand near Newbern, and where it is used largely as a truck soil. No. 5259 represents the heavier phase of this type, and Nos. 5257 and 5261 represent the lighter phase as well as the largest area. The subsoils for all the variations are rather stiff, except No. 5254 of the truck soil, which is sometimes quite sandy and incoherent.

Mechanical analyses of Norfolk fine sandy loam.

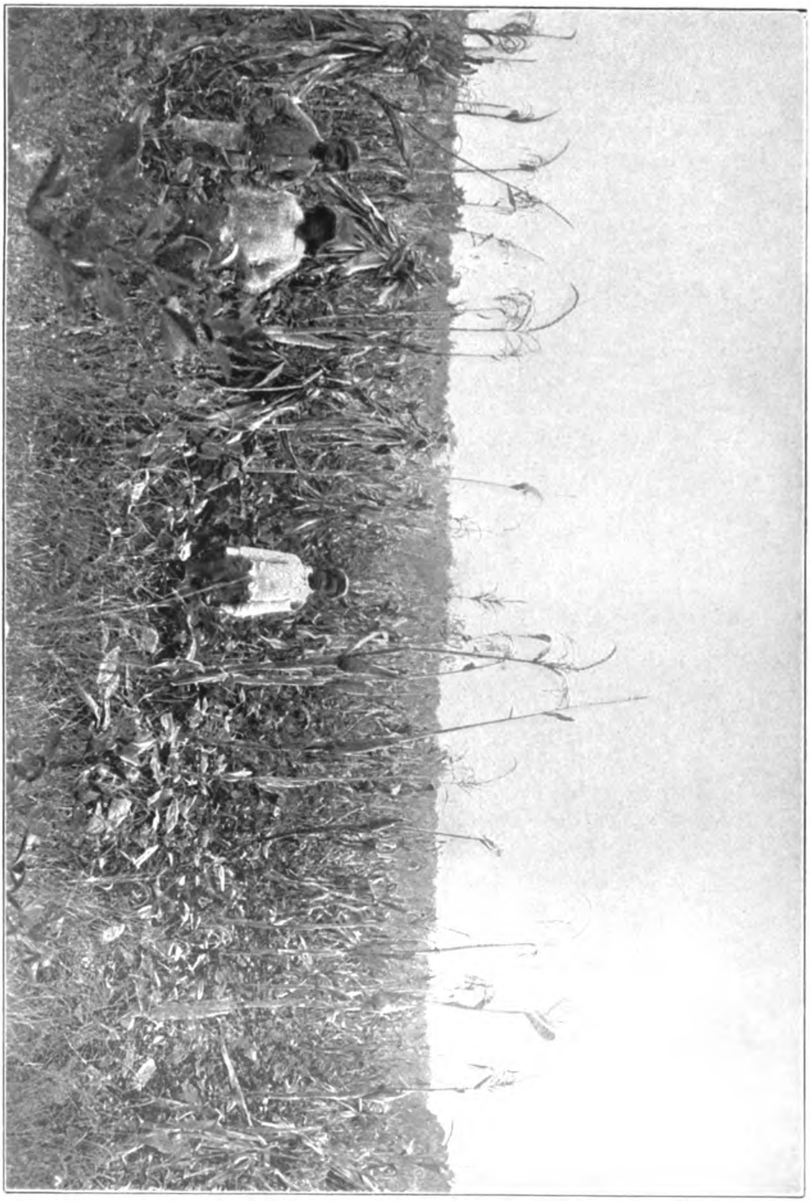
No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5253	2¼ miles W. of Newbern.	Medium fine sandy loam, 0 to 15 inches.	1.55	Tr.	3.18	4.24	46.56	21.15	6.91	16.00
5254	Subsoil of 5253	Yellow sandy clay, 15 to 40 inches.	1.83	Tr.	2.70	5.38	54.86	17.16	4.81	13.13
5257	4 miles NE. of Kinston.	Fine sandy loam, lighter phase, 0 to 15 inches.	2.03	1.14	4.36	7.28	43.30	26.54	11.91	3.32
5258	Subsoil of 5257	Yellow sandy clay, 15 to 36 inches.	3.36	1.55	3.51	5.28	31.43	15.01	9.70	29.57
5259	2¼ miles W. of Newbern.	Fine sandy loam, heavier phase, 0 to 10 inches.	2.40	.64	9.32	21.10	16.92	7.94	27.77	13.75
5260	Subsoil of 5259	Stiff mottled-gray clay, 10 to 40 inches.	3.57	Tr.	5.62	11.04	9.58	3.83	22.44	43.70
5261	3 miles W. of Tarboro (test farm).	Fine sandy loam, lighter phase, 0 to 18 inches.	.90	0.00	Tr.	1.26	54.10	26.15	12.49	4.79
5263	Subsoil of 5261	Stiff yellow clay with trace of sand, 18 to 40 inches.	2.81	Tr.	.64	.52	40.32	20.06	13.10	23.12

NEUSE CLAY.

The Neuse clay is a stiff silty or fine sandy loam, from 10 to 20 inches deep, gray in color, and underlaid to a great depth with a stiff, mottled-clay subsoil. In the present survey it occurs along the Neuse River near Kinston and in and around Tracy Swamp, about 2 miles north of Dover station. Along the Neuse River it is known locally as mud-bottom land, and is there subject to overflow; here it is generally left to a dense growth of cypress, gum, ash, alder, vines, and rank grass, and is used as a pasture run for hogs and cattle.

Tracy Swamp is subject to standing water to a depth of from 3 to 6 feet during periods of much rainfall. It is used in dry seasons as a pasture run. Attempts are being made to reclaim this area by ditching and draining it into the Neuse River, which, if successful, will open up some fine cotton land. The forest growth of cypress, gums, etc., is the same as that described for this type along the Neuse River.

To the north of Tracy Swamp, separated off on the map by a dotted line, lies a large area of Neuse clay elevated high enough not to be so much subject to standing water, making tillage to some extent possible. Here the area is quite flat, but drainage is possible by ditching. The forest growth is largely long-leaf pine. Cotton and corn do well when once rooted in this soil. On account of the soil becoming



CORN AND COWPEAS, SHOWING METHOD OF PULLING FODDER.

so dry and hard during droughty seasons that the plow can scarcely turn it, or so sticky in wet seasons that implements can barely move through it, this soil is generally difficult to till and does not possess a very good reputation among the local farmers. When loosened and dried out this soil dusts about under the feet like flour. The addition of barnyard manure or green crops plowed under would tend to make the soil more friable and productive.

The following table shows the mechanical analyses of the samples as follows: No. 5265 represents the large area of stiff-clay phase north of Tracy Swamp, near Dover station; Nos. 5266 and 5267 represent the lighter and friable phase found in Tracy Swamp and along the Neuse River, which areas are not much tilled at present on account of the poor natural drainage and frequent overflow.

Mechanical analyses of Neuse clay.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5265	5 miles N. of Dover.	Very stiff, gray, silty clay, 0 to 20 inches.	2.54	.32	2.46	2.26	12.68	10.60	41.46	26.12
5266	4 miles W. of Kinston.	Stiff, mottled, silty clay, 0 to 20 inches.	9.51	.00	1.38	4.30	13.36	7.52	35.04	28.84
5267	2 miles W. of Dover.	Stiff, mottled-gray clay, 0 to 20 inches.	9.87	Tr.	2.72	3.35	20.16	14.64	37.80	10.80

SAVANNA.

The Savanna land is a type due to location instead of soil character. It is a flat area surrounding the Pocoson land near Newbern, subject to from 6 to 20 inches of standing water during rainfall, but artificial drainage is possible over most of this area. The natural forest growth consists mainly of long-leaf pine, gum, and oak. In this area occur numerous depressions, from 3 to 8 feet deep and from 100 to 300 feet or more in diameter, which generally contain standing water and a dense growth of water cypress. The openings left by the removal of the lumber pine support a dense growth of rank grass and shrubbery, which seems to furnish good pasture nearly the entire year.

The soil is similar in texture to that of the Norfolk fine sandy soil at a depth of 8 or 12 inches, and is generally underlaid with a mottled, rather stiff yellow-clay subsoil. Where the Savanna land borders the truck soils, it possesses from 8 to 12 inches of rather loose, gray, sandy loam, which grades quickly into the stiff clay subsoil. Where the

Savanna land is well drained it is very productive for cotton, corn, and grass crops.

The following mechanical analyses of samples of soils and subsoils show the similarity in texture of this type to that of the Selma heavy silt loam (5268) and the Norfolk fine sandy soil (5270), both phases at a depth of from 8 or 12 inches, grading rapidly into a heavy clay subsoil:

Mechanical analyses of Savanna.

No.	Locality.	Description.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.5 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5268	3 miles W. of Newbern.	Heavy gray silt loam, 0 to 8 inches.	2.76	1.30	1.48	2.18	32.54	20.38	27.42	11.58
5269	Subsoil of 5268	Stiff mottled gray clay, 8 to 36 inches.	4.31	Tr.	.72	.72	11.76	11.11	22.80	48.24
5270	4½ miles W. of Newbern.	Loose gray sandy loam, 0 to 8 inches.	4.24	.34	4.13	8.35	42.45	13.21	19.27	7.07
5271	Subsoil of 5270	Yellow mottled clay, 8 to 36 inches.	3.30	Tr.	1.71	5.95	28.68	8.91	16.50	34.25

POCOSON.

The Pocoson area possesses a character distinctively incident to location. Generally speaking, it is a swampy area, depressed from 2 to 10 feet below the surface of the surrounding land. The typical Pocoson consists of a black, spongy, mucky soil, supporting a scattering growth of scrub pine, a dense undergrowth of gallberry shrubs, wire grass, and broom sedge, and all woven together with brier vines. During moderately dry seasons this affords a pasture run for cattle and hogs—after they learn to get through the almost impassable matting. The scrub pines are 6 or 8 inches in diameter and from 20 to 30 feet high, and are useful for firewood, fence posts, and a poor grade of timber. During dry seasons these areas are sometimes subjected to fire, rendering them useless for a long time for cattle and hog runs because of the almost complete burning of the muck soil and the shrub and grass growth. Generally, however, these areas are subject to standing water, especially in the winter season.

Through these Pocoson lands extend extensive ridges and knolls, from 3 to 6 feet higher than the mucky area just described. These generally possess a soil similar in texture to that of the Goldsboro compact sandy loam, supporting a strong growth of commercial longleaf pine. On the margin of these ridges often occur small spots of gum and cypress swamps and irregular strips of canebrakes. At a

CHARACTERISTIC GROWTH ON POCOSON.

depth of from 10 to 15 inches the soil of these ridges generally grades into a sandy clay subsoil. When drained and tilled these ridges yield good crops of cotton, corn, and grass.

The Pocoson land of the present survey consists of a large tract between Dover and Cove post offices, known as the Dover Pocoson. There are also small areas of this land near Newbern, Goldsboro, Lagrange, and Kinston. About one-half of the Dover Pocoson consists of the knolls and ridges of the gray sandy loam above mentioned. At Goldsboro, Lagrange, and Kinston these areas have also a soil similar to these ridges—a gray sandy loam which is capable of tillage when drained. Three miles south of Lagrange, in the Pocoson area, there is about 2 square miles of the black spongy soil above mentioned, known locally as "buckleberry soil." A portion of this soil is cultivated and yields well of corn, cotton, grass, and some vegetables when well ditched. All crops tend to a rank growth, because of the large amount of humus present in the soil.

MUCK.

The muck soil consists of varying amounts of vegetable mould, mixed with fine sand and clay, generally underlaid at a depth of from 2 to 6 feet, with a substratum similar in character to the adjacent land. In the present survey it occurs generally along the upper courses of small slow-moving streams, which are usually headed in large flat areas. Where drained, some of these soils yield large crops of hay, as well as corn and truck. The natural growth consists of cypress in the very wet swampy phases and alderbush, gum, willow, broom sedge, and rank grass on the more elevated and tillable phases.

MEADOW.

This term, as used in the present survey, stands for a low-lying flat, usually poorly drained, land along the larger streams. It figures mostly as a narrow margin along the Neuse River and its larger branches from Raleigh to Goldsboro, where it ceases to appear any more, because of the soil admitting of being classified with other types having a more specific texture. The meadow soil is a river deposit 3 feet or more deep, varying from a clay to a sandy loam. As used here, however, it generally consists of a rather deep, fine sandy or silty loam. It is a fertile soil, easily tilled, and adapted to grass and pasturage and occasionally to general farming where drainage is possible. The forest growth consists largely of willow, alderbush, and gum.

SOIL SURVEY IN WEBER COUNTY, UTAH.

By FRANK D. GARDNER and CHARLES A. JENSEN.

INTRODUCTION.

The area considered under the above title, situated in the northern section of Utah and mostly in Weber County, is bounded on the east by the Wasatch Mountains and on the west by Great Salt Lake. In extent it is approximately 18 miles east and west by the same distance north and south, and includes 310 square miles, or 198,400 acres, of land, of which 25,000 acres are in Boxelder County and 22,000 acres in Davis County.

This district comprises three prominent features: First, an area of sloping land adjacent to the base of the mountains and usually formed directly from them; second, a larger and more level area farther removed from the mountains which has been formed by material brought from the interior of the ranges by the action of the Weber and Ogden rivers; and, third, a very level area, the upper portion of which is a deposit of the present Great Salt Lake, which within the memory of the present inhabitants has emerged from that body of water.

The first feature is characterized by a rapid slope from the mountains, by an uneven surface, with hillocks and escarpments, the latter marking the shore lines of the ancient vacillating Lake Bonneville, and by a stony or gravelly surface. The land usually lies above the present irrigation systems and is consequently but little farmed, except where used for the production of wheat without irrigation.

The second feature is a comparatively level stretch of country, usually sandy and quite free from gravel, having a gentle slope toward the lake. It is a low, flat delta which, as shown by the character of the soil and the many abandoned river channels in different parts, has been formed by material brought down by the Ogden and Weber rivers within comparatively recent times. It is to this part that agriculture is at present mostly confined.

About Ogden, North Ogden, Plain City, Hooper, and the intermediate country the rural population is quite dense, and the farms, usually small, are devoted to an intensive system of agriculture. On the better lands peaches, pears, prunes, and plums are successfully grown. Sugar beets furnish the raw material for one large beet-sugar factory, and tomatoes are grown in sufficient quantities to supply eight canneries. Other truck crops are also grown.

The third feature embraces about 60,000 acres, and is characterized by extremely smooth, level surfaces and intensely salty conditions

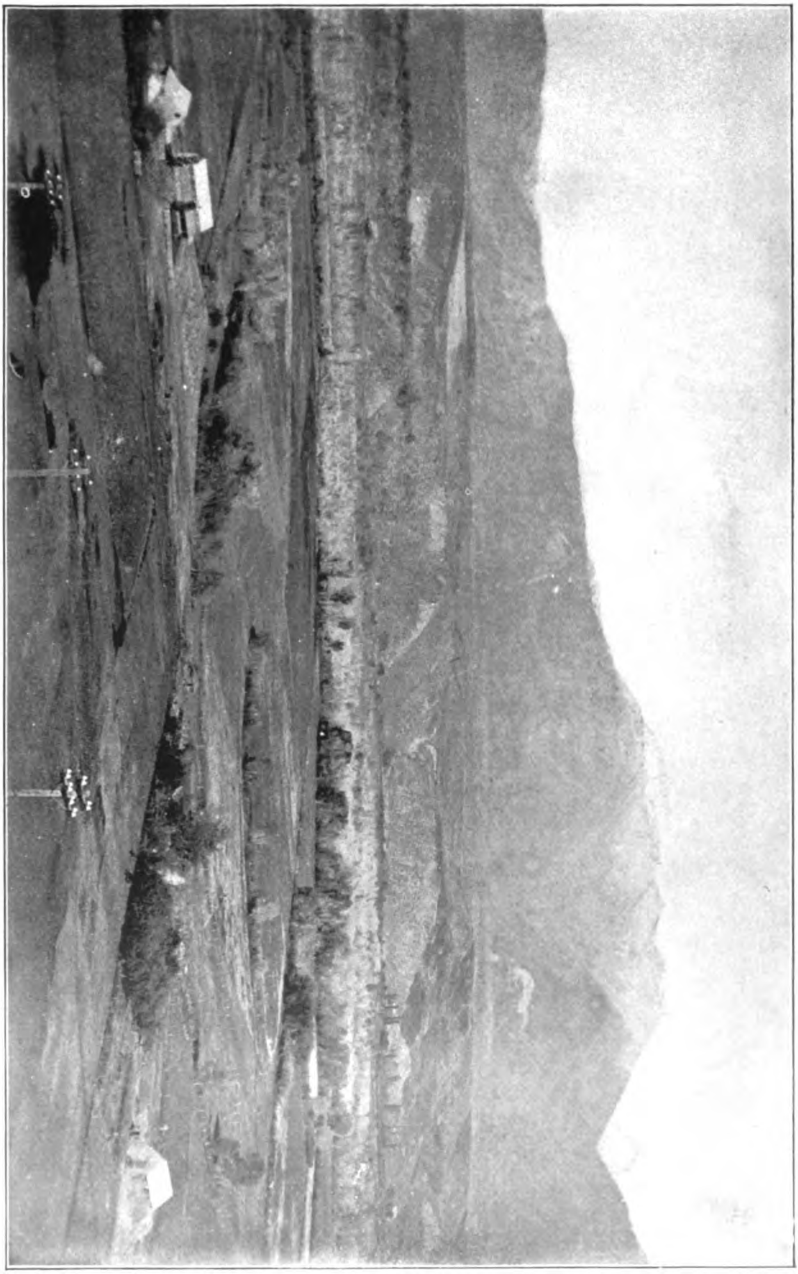
and consequent lack of vegetation. Within the memory of the older inhabitants it has all been submerged by the waters of Great Salt Lake, which accounts for its salty and barren condition.

The entire area of this survey lies within the Bonneville Basin, which is a subdivision of the Great Interior Basin, and all of the land here considered has been submerged by that ancient lake except the lower portion, where in part the surface has been made since the recession of the waters. In 1899 a survey similar to this one was made in Salt Lake County, Utah, a full report of which is contained in Report No. 64 of the United States Department of Agriculture, entitled "Field Operations of the Division of Soils, 1899." The reader is referred to that report for a brief description of the Great Interior Basin and its subdivisions, a knowledge of which is quite essential to a clear understanding of some of the conditions which will be discussed in subsequent pages of this report.[1]

The Wasatch range of mountains, which borders the district on the east, extends northward to the Bear River Canyon and southward for some distance beyond Utah Lake, the total length of the range being approximately 200 miles. The mountains face the west with a bold front, rising abruptly to a height of from 5,000 to 6,000 feet above the valley, or about 10,000 feet above sea level. One remarkable feature of this range is its backbone of Archæn rock, which crops out at various places, namely, just north of Ogden, just east of Ogden, beginning north of Uinta and extending south for about 25 miles, and just south of Salt Lake City. This Archæn rock was the backbone and modeler of the Wasatch range, and stood during the rock-making period of the Paleozoic and Mesozoic times. It is considered a western spur of the protaxis of the Rocky Mountain system. Above and around this rock are represented nearly all the rocks of the Cambrian, Silurian, Devonian, and Cretaceous eras, including the Upper Cretaceous. The rocks from north of Ogden to and beyond Salt Lake City are very much flexed, not only into folds having an east and west flexure, but also into others having east and west axes superimposed on each other. From Ogden the strata bend eastward to Weber; then westward to the Great Gap, where all of the above-mentioned rocks are found. Here the flexure was so great that it became disastrous to the strata, which are broken through. From the Gap southward there is a folding, the direction of its axis at the Gap being nearly due east and west, from which the outcrop extends westward and again southwestward.

North of the Uinta Mountains is the great Wasatch Eocene Basin, and south of this range is the Uinta Eocene Basin. Between the necks of these basins, east of the Gap, is quite a large area of igneous rock (trachyte), accompanying or succeeding the enormous warping and flexing which here took place. The Wasatch Eocene

[1] For a full report on Lake Bonneville, see monograph by G. K. Gilbert. U. S. Geological Survey, 1890.



VIEW ACROSS THE WEBER VALLEY NEAR UINTA.

This narrow valley has been cut through the old delta within comparatively recent times.

Basin and the Uinta Eocene Basin were formerly the Wasatch and Uinta lakes of the Eocene epoch; and the Great Salt Lake is a remnant of the Cretaceous sea which during that era (maximum submergence during the Upper Cretaceous) probably extended from the Gulf of Mexico to the Arctic region. This area is of great interest to the geologist as revealing a great majority of the steps of mountain making in the continent from the very beginning of geologic history to the present time. It is from this great diversity of rocks that the soils of the Ogden district have been formed through the action of weathering and transportation.

Topographically the area varies in elevation from the present level of the lake, which is slightly less than 4,170 feet above sea level, to the Bonneville shore line, which is 1,000 feet higher. Near the mountains the land slopes quite rapidly and is in many places quite uneven. Farther back it becomes quite level and slopes gently toward the lake, becoming very level near the shores of that body of water.

A very large delta occurs at the mouth of the Weber Canyon as a result of material brought down during the Bonneville period by the Weber River. It extends as far west as the railroad tracks, with a mean height of fully 300 feet above the present river channel, the river having cut down to this depth since the Bonneville period, and thus formed a narrow valley from half a mile to a mile in width, having abrupt bluffs on either side. A similar delta, though not as large, was formed by the Ogden River.

CLIMATE.

The climate is characterized by low annual precipitation, moderate temperature, moderate wind movement, low relative humidity, and abundant sunshine. According to the thirty years' record at Ogden, kept by the United States Weather Bureau, the mean annual rainfall is 14.1 inches. Of this amount, only 1.9 inches fall during the months from June to September, inclusive, and as this is the period during which crops make most of their growth, irrigation water is very essential to the practice of agriculture. The climatological data are shown in the following table:

Monthly and annual precipitation at Ogden, Utah, 1896 to 1900, and the mean for thirty years.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896	1.62	0.30	2.87	1.25	3.57	0.10	0.20	0.28	0.58	0.70	1.93	0.95	13.95
1897	1.80	2.85	2.37	1.70	.30	.98	Tr.	......	.55	1.93	1.51	2.25	16.24
1898	1.47	.16	1.82	.37	5.23	.81	.00	.30	.30	1.47	1.12	.60	13.68
1899	1.25	1.98	2.65	.53	.89	.98	Tr.	.45	......	2.45	.85	1.50	13.53
1900	.20	1.08	.10	1.93	1.10	.31	.15	.28	1.32	2.01	3.87	.18	12.53
Mean for 30 years	1.7	1.5	1.8	1.5	1.5	.6	.2	.4	.7	1.3	1.1	1.8	11.1

On the sandy uplands above the irrigation canals some wheat is grown by dry farming, but the yields are moderate, and in years of low rainfall are sometimes a failure. No other crops are profitably grown except by irrigation.

The annual precipitation in the mountains is greater than in the valleys, and it is estimated that it includes 6 feet of snow, which lingers on the mountains the greater part of the summer. This is important in relation to irrigation, because it makes the water supply plentiful throughout the season.

The annual evaporation from a free water surface in this section of the State is estimated at 8 feet. Data from the Inland Salt Company at Saltair show the evaporation from their ponds to be about 37 inches from June to September, inclusive. It should be borne in mind, however, that this is from a saturated salt solution, and that the presence of much salt lowers the vapor tension, and consequently the rate of evaporation. The evaporation from a fresh-water surface would no doubt have been much greater.

During the present year Great Salt Lake has fallen from 2 feet 7 inches above the zero mark on June 15 to 6 inches below said mark on October 15, the fall being 37 inches in four months, or exactly the same as the evaporation from the above salt ponds for the same length of time but in a different year. This fall in the water of the lake is believed to be entirely due to evaporation, but it does not represent the entire amount of evaporation. Small streams of water from the rivers and from springs, which occur around the periphery of the lake, are at all times sending water into the lake, and there is also a small amount of rainfall during this period. The record further shows that the fall of the lake from August 15 to October 15 was 24 inches, this being the time when the streams flowing into the lake become very low and the fall represents more nearly the true evaporation from the lake surface. The conditions for the two months preceding August 15 are favorable to a greater evaporation than they are for the following months, and it is safe to say that the total evaporation from the lake surface from June 15 to October 15 exceeds four feet by several inches. It must be borne in mind that the lake water contains 22 or 23 per cent of salt, which considerably lessens the vapor tension, and therefore makes the evaporation from its surface less than would be the case from a surface of nearly pure water.

HISTORY OF IRRIGATION.

The first irrigation in the State of Utah was at Salt Lake City in the year 1847. In fact, this undertaking of the Mormons in that year marks the beginning of modern irrigation in the United States. Traces of irrigation antedating that of the Mormons at Salt Lake City have been found in New Mexico and Arizona (in the systems, long since abandoned, of an extinct race of aborigines) and in southern California, where irrigation was practiced by the Mission priests. From

the region of the present Salt Lake County the Mormons soon spread to various sections of the State, and as early as 1850 irrigation works were constructed along the streams in what is now Weber County. At Ogden the Lynne Irrigation Canal was constructed in 1850 by the cooperative labor of the settlers, and in a similar way the Pioneer Canal near Uinta was built in 1851; while in the following year the Uinta Central Canal was built. Following these, the Plain City Canal was built for a distance of 10 miles, the work being done by the use of shovels and wheelbarrows. The Hooper Canal, which furnishes water for the settlement of that name, was not built until 1867. Since first built it has been enlarged and its head gates placed farther up on the river, so that it now has a capacity of 150 second-feet of water at its intake and a capital stock of $80,000.

Two important canals of quite recent construction are those of the Pioneer Power Company and the Davis and Weber Counties Irrigation Company. The last named has a capital stock of $250,000, which includes the controlling stock in a large reservoir some distance above the Devils Gate on the Weber River. This canal has a capacity of 125 second-feet of water, and being the highest of the canals taken from the Weber River, its water supply is plentiful and always of the best quality. The land also which it is intended to irrigate is higher than most of the irrigated lands, and is quite free from alkali.

The canal system of the Pioneer Power Company is elaborate, and includes 35 miles of mains and laterals. The main branch is 30 feet wide on the bottom and carries a depth of 5 feet of water. The system is said to have cost the company about $100,000. It irrigates a large tract of level land lying west and southwest of Plain City. As yet not enough land is being farmed under either of the two last-named canals to utilize all the water they are capable of bringing to the lands. There are numerous other canals, the names and locations of which will be found on the maps accompanying this report. With the exception of the dates of construction and the size, the history of these canals would be largely a repetition of the above. Complete data as to the acres of land irrigated have not been obtained, but it is roughly estimated at from 35,000 to 40,000 acres, or about 20 per cent of the area which has been mapped.

That there is a large loss of irrigation water by seepage and evaporation during transit through canals and laterals from the streams to the land where it is to be applied there can be no doubt. There is a large percentage of irrigated land that is too wet during a considerable part of the year for the best results to be attained. This undue wetness comes principally from leaky canals and from over-irrigated lands. There is great need of unusual care to prevent this loss, especially in a district where land and water are both so valuable as in Weber County. It is not only a loss of irrigation water, but also a damage to many acres of land. In the vicinity of Plain City and about Hooper many acres of land which were once profitably farmed

are now lying idle because of their wet condition and consequent small accumulation of alkali at the surface, just sufficient to interfere with the growth of crops. There are thousands of acres of this wet land that by a small expenditure for underdrainage could be made as valuable as the best lands in the district. The small amount of alkali which has accumulated at the surface would, upon the lowering of the water table and application of irrigation water, soon be disseminated in the lower depths of soil where it would do no harm to crops.

The canals are owned for the most part by the owners of the land under irrigation, and the only paid officer is the "water master," whose duty it is to attend to the equitable distribution of the water to the shareholders. At stated intervals along the main canals laterals are taken out to supply the farms along its course. Each lateral has a head gate, the opening or closing of which is controlled by the water master, and the size of the opening is varied according to the number of shares supplied by the lateral and the total water supply for the canal. If the water supply is plentiful, the gates usually remain with a certain-sized opening throughout the season, and the water is permitted to flow continuously. Each shareholder is entitled to use all of the water flowing in the lateral for a stated number of hours and at stated intervals, according to a schedule agreed upon at the beginning of the season.

SOILS.

The soils have been classified under eight types, in the order of the magnitude of their respective areas, as follows:

Classification of soils by areas.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Fresno fine sandy loam	86,400	43	Meadow	7,700	4
Salt Lake sandy loam	49,900	25	Bingham stony loam	5,700	3
Fresno sand	21,800	11	Jordan sand	1,900	1
Jordan loam	15,400	8	Total	198,400	100
Salt Lake loam	9,600	5			

FRESNO FINE SANDY LOAM.

This sandy loam comprises 86,400 acres, or 43 per cent of the entire survey, and is agriculturally the most important of the soil types in this area. Leaving out of consideration the land beyond the old shore line, none of which can for some time be used for any agricultural purpose, the Fresno fine sandy loam constitutes nearly two-thirds of the remaining portion. This soil is divided into two phases, the smaller and least important constituting the sloping land which lies nearest the mountains, and the larger and more important constituting the level area extending out to the old shore line of Great Salt Lake. The sloping land near the mountains usually contains small to medium gravel within 3 or less feet of the surface, and when not within this distance it is usually present at some greater depth. This por-

tion is naturally well drained and free of injurious amounts of alkali, a fact which is well brought out by a study of the alkali and underground water maps. A considerable part of this sloping land lies above the present irrigation canals, and where thus situated it is frequently used for wheat production under dry farming. Where irrigation water is available the more gravelly parts of this land are considered the highest type of peach land, and, indeed, the greater part of this gravelly soil is admirably well adapted to the production of peaches and other stone fruits. As a rule, it is not well adapted to apples and pears, although there are small areas where the gravel is absent or far below the surface where these fruits will do well.

The larger and more level phase of this soil type is usually free from gravel, and where well drained and free from alkali it forms an excellent soil for alfalfa, grain, sugar beets, tomatoes, small fruits, general truck crops, and also for apples and pears.

The following table of mechanical analyses shows the texture of the soil for the first, third, and fifth feet in depth in various places:

Mechanical analyses of Fresno fine sandy loam.

No.	Locality.	Description.	Salts as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Fresno fine sandy loam, 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5046	One-fourth mile S. of C. sec. 9, T. 7 N., R. 2 W.	Dry virgin soil	0.13	1.59	.00	Tr.	4.84	32.68	33.10	22.98	4.16
5049	One-fourth mile E. of N. C. sec. 21, T. 6 N., R. 3 W.	do	.33	2.46	.00	.00	2.42	49.15	18.54	21.53	4.69
5068	One-fourth mile W. of C. sec. 27, T. 5 N., R. 1 W.	Low gravelly land, 6 per cent of gravel.	.35	3.22	1.76	1.54	2.36	28.06	34.77	22.33	5.71
5043	One-fourth mile E. of C. sec. 5, T. 6 N., R. 3 W.	Dry virgin soil	.57	2.24	Tr.	.47	.81	16.33	45.44	27.63	6.29
5069	One-fourth mile E. of N. C. sec. 21, T. 5 N., R. 1 W.	Dry farmed land	.17	2.80	.00	Tr.	1.70	22.68	43.90	22.36	6.62
5073	C. of NE. ¼ sec. 17, T. 6 N., R. 1 W.	Dry level land, 24 per cent of gravel.	.44	4.80	1.89	3.41	2.23	11.35	28.40	40.84	7.30
5053	C. of SW. ¼ sec. 24, T. 5 N., R. 3 W.	Low, salty land	1.49	4.20	.00	1.12	3.40	26.84	31.56	23.59	8.68
5055	N. C. sec. 36, T. 6 N., R. 2 W.	Wet, salty land	1.13	2.71	Tr.	4.29	12.43	30.68	17.08	22.40	9.37
	Mean		.58	3.00	.46	1.35	3.77	27.22	31.60	25.46	6.63
	Subsoils.										
5047	Sandy loam, 24 to 36 inches.	Under No. 5046	.62	4.92	.62	1.62	3.60	24.56	25.98	25.46	11.66
5048	Sand, 48 to 60 inches	do	.42	1.44	.00	2.09	20.34	55.06	13.09	2.68	3.76
5050	Sandy loam, 24 to 36 inches.	Under No. 5049	.66	3.24	.00	Tr.	2.37	58.98	16.94	11.12	7.67
5051	Sand, 48 to 60 inches	do	.40	2.47	.00	Tr.	5.82	79.38	9.97	.18	1.72
5054	Sandy loam, 24 to 36 inches.	Under No. 5053	1.17	1.93	Tr.	3.22	5.80	30.18	36.60	12.91	9.03

These analyses show that the soil is made up principally of the two finer grades of sand and silt, the sand giving to the soil its character. In clay content it is unusually low for a sandy loam, having in the surface foot from 4 16 to 9.37 per cent, with a mean of only 6.5 per cent. In the second and third foot in depth the soil usually becomes slightly heavier, a fact which is brought out in the analyses of the third-foot samples, which contain an average of 8.93 per cent of clay. Below this the soil again becomes more porous, containing less clay and more fine sand. The two samples here given are somewhat too sandy for the average conditions at 5 feet, but represent that part in which sand forms the subsoil.

A profile of this type of soil shows that the first-named phase of it is a sandy loam to a depth of 6 feet or more, with medium-sized, usually rounded-gravel occurring on an average from 18 inches below the surface downward. In many places the gravel comes directly to the surface, while in other places it is 3 feet or more below the surface.

The second phase, that is the level and larger portion of this type, shows two conditions of substratum. About half of it consists of 4 feet of fine sandy loam, underlaid by sand to an undetermined depth, while the remainder is fine sandy loam for 6 feet or more in depth.

A knowledge of the character of the underlying stratum is of the utmost importance in relation to soil drainage. Conditions are here found which are very favorable to underdrainage. The gravelly portion of this type of soil has abundance of slope and is always well drained. If the lower portion had an equal slope it would also be well drained. However, it is a large tract of level land which has very few avenues, in the form of streams or deep cuts, by which the ground water can escape. As a result, practically all of the water which reaches this land, in excess of that which is evaporated from the surface of the ground and that which is transpired by the vegetation, is added to the gravitational ground water, thus raising the level of the ground-water table. The excess of water added by irrigating for a long series of years has raised the water table until it is now dangerously near the surface in many places, as shown by the underground-water map. The elevation of the water table too near the surface is also accompanied by an accumulation of alkali at the surface; and the combined effect of these two agents has rendered many acres of otherwise valuable land unfit for the production of any kind of agricultural crops.

The lower portions of this type of soil in their virgin state are very salty in the lower depths. This is accounted for by the fact that the land has been submerged by the waters of the lake within comparatively recent time. Upon subsidence, the salty water of the lake would naturally leave the soil heavily charged with salts. A discussion of the alkali and the ground-water problem will be taken up in subsequent pages.

SALT LAKE SANDY LOAM.

This type of soil, while representing nearly 50,000 acres of land or one-fourth of the whole district, is of practically no value for agricultural purposes, because of its location and extreme saltiness. It is all recent lake bottom, and as late as 1885 was practically all submerged by the salty water of Great Salt Lake. All previously constructed maps of the district show this portion as a part of the lake. The present survey moved the shore line westward to its true position in October, 1900, thus adding to the district about 60,000 acres of land which has previously always been mapped as water. In 1868 the water was 14 feet above the water level of 1900, and at that time submerged considerable land that was shown as such on the older maps.

This type of soil is a sandy loam for 18 inches in depth, below which is usually fine sand. In places it is underlaid at from 1 to 2 feet by beds of mirabilite, that is, sodium sulphate containing water of crystallization which is thrown out of solution in the lake when the water reaches a critical temperature, and often heaped upon the shores in considerable abundance, where it is afterwards covered over by sand or soil.

The ground-water map shows that, under the greater portion of this type, water stands at 3 feet or less from the surface. Near the old shore line it is sometimes 4 feet below the surface. The unaided eye is unable to detect any slope in the land; and, indeed, it is nearly level, having a surface as smooth as a house floor. There is a slight fall, usually of only a few inches to the mile, toward the lake.

As shown on the alkali map, this land is all very salty, containing from 3 to 10 per cent of salt in the upper 6 feet. It is estimated that there are not less than 50,000,000,000 pounds of salt in the first 6 feet of soil over this portion of the district, or sufficient at the rate of 20 tons to the car, each car 30 feet in length, to make a continuous train 7,100 miles long, or twice the distance from New York to San Francisco.

If the lake continues to recede, two or three generations hence may see this land comparatively free from salt, and some of it used for agricultural purposes.

FRESNO SAND.

Fresno sand is third in point of extent and second in agricultural value. It embraces 21,800 acres, or 11 per cent of the entire area, and like the Fresno fine sandy loam it occurs in two phases—an elevated portion with considerable slope, frequently containing gravel and always well drained, and a low, level portion always free from gravel and sometimes troubled with alkali and wetness. The lower portion extends from Hooper in a northeasterly direction to the Weber River as a narrow strip, with a number of isolated areas to the east as a chain running in the same direction. This portion has been largely

under irrigation for many years by the Hooper and Wilson canals, and in places has been greatly damaged by the accumulation of alkali and seepage from overirrigation and from leakage from the canals. The larger sloping area was not irrigated until the construction of the Davis and Weber counties canal a few years ago. It is all well drained and free from injurious amounts of salts. At present about 5,000 acres are under irrigation, and of that portion above the canal considerable is used for wheat under dry farming.

The following table of mechanical analyses shows the texture of this type of soil:

Mechanical analyses of Fresno sand.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Fresno sand, 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5059	NW. C. sec. 35, T. 5 N., R. 2 W.	Virgin sandy soil.	0.31	1.43	0.00	0.96	5.32	53.15	31.71	3.78	2.87
5056	SW¼ sec. 13, T. 5 N., R. 3 W.	Sandy truck soil.	.29	2.06	Tr.	4.14	12.03	55.20	18.51	3.91	3.28
5066	N. C. sec. 36, T. 5 N., R. 2 W.	Virgin sandy soil.	.12	1.55	1.50	23.08	22.27	23.44	15.23	7.39	4.69
5065	One-fourth mile east of C. sec. 14, T. 5 N., R. 2 W.	Gravelly sandy soil.	.10	2.39	5.40	13.50	9.77	13.54	15.78	32.76	6.53
			.20	1.86	1.72	10.42	12.35	36.33	20.31	11.96	4.34
	Subsoils.										
5060	Sandy loam, 24 to 36 inches.	Under 5059	.34	1.45	0.00	1.42	2.83	35.21	40.11	13.47	5.11
5061	Sandy loam, 48 to 60 inches.	do	.22	4.03	.71	5.22	5.52	21.60	12.29	41.52	10.34
5057	Sand, 24 to 36 inches.	Under 5056	.37	3.04	Tr.	3.49	10.41	58.89	16.54	2.66	4.72
5058	Sandy loam, 48 to 60 inches.	do	.52	3.68	.47	3.65	6.38	41.30	15.04	19.40	10.48
5067	Sandy loam, 24 to 36 inches.	Under 5066	.18	1.63	Tr.	1.96	10.74	9.45	23.58	33.80	8.21

The analyses show that while this type of soil contains about the same amount of clay as the Fresno fine sandy loam, it is lower in very fine sand and silt and much higher in coarse and medium sand. It is this loose, incoherent texture, together with its position and natural drainage, that makes it especially well adapted to fruit and truck crops. A profile of this type of soil shows it to be a sand, continuing in about the same texture for an undetermined depth, with gravel occurring in the higher portion both east and west of Riverdale, sometimes coming directly to the surface and at other times being at a considerable distance beneath. The gravel is from small to medium in size and does not interfere with cultivation.

In the vicinity of Hooper this type of soil is used for sugar beets, tomatoes, peaches, plums, prunes, and pears. When the ground water is kept 4 feet or more below the surface all of these crops do

well, but with water nearer than 4 feet fruit trees generally are a failure and alkali not infrequently appears near the surface. About Hooper there are small areas where black alkali has accumulated in sufficient amounts to be harmful, although the total salt content is not high. The higher portion is well drained, free of salts, and, while it is at present used only for tomatoes, sugar beets, and alfalfa, a large part of it is also admirably adapted to general fruit culture.

JORDAN LOAM.

This type of soil ranks fourth in point of extent and third in agricultural value. It embraces 15,400 acres, or about 8 per cent of the entire area, and takes its name Jordan from its similarity to the loam described under that name in Salt Lake County in 1899.

The table following shows the mechanical analyses of Jordan loam:

Mechanical analyses of Jordan loam.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5062	One-fourth mile E. of N. C. sec. 16, T. 5 N., R. 2 W.	Virgin soil	2.75	6.82	4.00	4.46	2.18	8.10	16.64	41.91	13.63
5074	NE. C. sec. 8, T. 6 N., R. 1 W.	Sloping land	.98	4.75	Tr.	.54	.94	2.00	15.22	56.27	18.45
	Subsoils.										
5063	Loam 24 to 36 inches	Under 5062	.74	6.98	8.44	10.88	4.86	7.96	20.72	29.58	10.76
5064	Loam 48 to 60 inches	.....do.....	.49	3.52	1.28	2.46	1.29	2.52	27.14	45.52	14.62
5075	Clay loam 24 to 36 inches.	Under 5074	1.17	5.69	Tr.	1.50	.65	2.06	9.29	46.57	32.81
5076	Clay loam 48 to 60 inches.	.....do.....	.97	6.06	Tr.	.93	.72	3.72	10.84	48.67	27.95

The above table shows the results of mechanical analyses for the first, third, and fifth foot in depth for this type of soil. The average conditions show a loam soil continuing to 6 feet or more in depth, but in places it is underlaid by sand below 2 feet in depth, while in other places it is underlaid at the same depth by a substratum of clay several feet in thickness. This type of soil occurs in more or less isolated bodies scattered throughout the district, and usually occupies the lower levels or slight depressions.

The largest and most important body of this type occurs in the vicinity of North Ogden, where a considerable part of it is under irrigation. In this vicinity the land is used for grain, alfalfa, and for pears and apples. It is well adapted to all of these crops when well drained, but where the water gets within 4 feet of the surface it will not do well in apples or pears, although grain will do well so long as alkali does not occur near the surface. This type of soil is not suited to the stone fruits.

The areas scattered over the remainder of the district are poorly drained and generally contain considerable alkali. They are frequently used for pasture, but are seldom cultivated. All of this type of soil lies so that it can be irrigated, and when reclaimed will make excellent land for grain and alfalfa.

SALT LAKE LOAM.

This is an unimportant type of soil which occurs principally in the northwest corner of the Ogden district. It is recent lake bottom, very salty, and absolutely bare of vegetation. It differs from the Salt Lake sandy loam described above only in point of texture, being largely silt with a somewhat larger percentage of clay. It is the finer material brought down by the combined action of the Weber River, which formerly emptied into the lake in this vicinity, as shown by several abandoned river channels, and the Bear River, which empties into the lake some distance beyond the northwest corner of this district.

MEADOW.

Meadow embraces 7,700 acres, or about 4 per cent of the Ogden district, and occurs along the present river courses or in their vicinity. It is usually wet land, a considerable part of which is subject to occasional overflow from both the Ogden and Weber rivers. It occurs in two phases, a gravelly portion along the present rivers, either bare or covered by a growth of small maples, willows, and other water-loving trees, and a larger and more important area lying as a low, level body of black soil northwest of Ogden. In its virgin state this latter phase is usually covered with grass, although in some places it is covered with maple and willows. The soil is black or dark colored, due to the large amounts of organic matter which it contains. It varies from a light sandy loam to a heavy loam, and is usually underlaid at 3 feet or more in depth by coarse river wash gravel.

The following table gives the texture of the more sandy part of this soil, as determined for the first and third foot in depth by mechanical analyses:

Mechanical analyses of meadow.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5071	One-fourth mile E. of C., sec. 20, T. 6 N., 1 W.	Black river bottom, 0 to 12 inches	0.48	5.64	Tr.	3.42	4.28	20.89	28.07	32.19	5.70
5072	Sandy loam, 24 to 36 inches.	Under 5071 ..	.50	6.11	0.91	2.83	3.24	14.70	26.83	39.08	6.50

This soil is free from injurious amounts of alkali, but is usually more or less wet. At the time of the survey there was none of it in which the water table was more than 6 feet below the surface, and along the railroad tracts northwest of Ogden there was a considerable area where the water came within 3 feet or less than 3 feet of the surface. This land needs drainage, and when properly drained its lighter parts make good land for truck, celery, and small fruits, its heavier parts being admirably adapted to cereals and forage crops.

BINGHAM STONY LAND.

Bingham stony land includes about 5,700 acres, or 3 per cent of the district, and occurs as rough land adjacent to the base of the mountains. It lies above all irrigation canals and is too stony to be cultivated. (It takes its name from similar land previously described in Salt Lake County, Utah.) It consists of a mass of broken rock and bowlders interlaid with fine material, the rock usually coming directly to the surface or projecting some distance above it. This grades down either to bed rock or broken rock in the lower depths. It is adapted to some extent to mountain pasturage.

JORDAN SAND.

Jordan sand previously described in Salt Lake County, Utah, includes about 1,900 acres, or 1 per cent of the area surveyed, and occurs usually as a loose, incoherent sand, frequently blown into dunes and either bare of vegetation or covered by rabbit bush. On account of its position, it is not cultivated. Where water is available it could be leveled and used for very early truck crops, but would probably need the application of manure to supply the soil with humus and make it more retentive of moisture.

The following mechanical analysis shows the texture of the sand, which is made up largely of medium, fine, and very fine grades of sand, there being very little silt and but a small percentage of clay:

Mechanical analysis of Jordan sand.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5070	NE. sec. 31, T. 6 N., R. 1 W.	Dunes, 0 to 12 inches.	.11	.80	Tr.	3.84	12.76	60.02	18.09	1.33	3.61

HARDPAN.

In certain areas, shown on the soil map by hatchings, a hardpan occurs as a thin stratum, usually from 18 inches to 3 feet below the

ground surface. This hardpan, usually from 2 to 4 inches thick, but sometimes more, occurs chiefly in the vicinity of Plain City, and particularly on alkali lands. It marks no change in the texture of the soil, for it occurs more frequently in the sandy loam, and the soil particles of the hard stratum are the same in both size and proportion as they are in the loose soil above and below it. This hard stratum is formed by an accumulation of lime carbonate, at this particular zone in the soil, sufficient in quantity to cement the soil grains together, just as lime is used to cement the grains of sand in the formation of mortar and plaster.

Under ordinary conditions, it is quite pervious to water and to the roots of plants, but when dry it is quite hard and difficult to dig. When moistened with water and soaked for a while it softens considerably, but does not disintegrate to any appreciable extent. It effervesces freely with hydrochloric acid and falls apart into a sandy loam.

As would be expected, the subsoil immediately below the hardpan is quite moist throughout the season, while above it the soil is quite dry during the summer months. The soil above the hardpan is usually free from excessive quantities of alkali, while below the hardpan the salt content is very much greater.

This type of hardpan has been previously encountered and described, but data adequate to explain its mode of occurrence at from 18 inches to 3 feet below the ground surface have been previously wanting. In view of data collected during the present season on the vertical distribution of alkali within the soil, as brought out under the head of "Alkali," together with certain experiments, carried on in the laboratory under the direction of Dr. Cameron, showing the effect of one salt upon the solubility of another when the two are brought together in water, as published in another part of this report, the following possible explanation of its occurrence is given.

The presence of soluble sulphates or chlorides will render the calcium carbonate more soluble than in pure water; but the major part of the calcium carbonate under soil conditions will go into solution as the hydrogen carbonate, more familiarly known as the bicarbonate. This salt (the calcium hydrogen carbonate) is more soluble than the normal carbonate, not only in pure water but in aqueous solutions of salts, such as the chlorides and sulphates. It is thus evident that calcium carbonate, which is but very slightly soluble by itself, can nevertheless be dissolved and transported by soil waters containing carbon dioxide (thus forming the more soluble hydrogen carbonate), especially when soluble chlorides or sulphates are present. But since the calcium salt enters the soil solutions almost entirely as the hydrogen carbonate, even when considerable amounts of chlorides or sulphates are in the solution as well, it is evident that the soil atmosphere and the proportion of carbon dioxide it contains must be considered. Calcium hydrogen carbonate is not a very stable salt,

and under conditions of stable equilibrium the amount which can be dissolved or will remain in solution is dependent upon the proportion of carbon dioxide in the atmosphere in contact with the solution.[1] The atmosphere of the soil, as has been shown by various investigators, is usually comparatively rich in carbon dioxide; always richer, certainly, than the atmosphere above the soil.

When water comes upon the surface of the soil from rain, flooding, or artificial irrigation, it passes down through the larger soil spaces rather quickly, more or less completely filling the soil spaces and dissolving not only the more readily soluble salts with which it comes in contact, but to a large extent the gases of the soil atmosphere as well. This solution in its passage downward through the soil and afterwards can and will dissolve calcium carbonate if it come into contact with this substance, this salt going into solution as the hydrogen carbonate until the solution becomes saturated with respect to it, under the conditions which exist in the solution.[2] When evaporation and desiccation recommence at the surface the soil solution, which had passed downward rapidly through the larger soil spaces, now begins to rise again, but slowly, and through the finer capillary spaces and contact films on the surfaces of the soil grains. As this process continues the larger interstitial spaces in the soil, which had become filled with the solution, are again emptied of it, leaving room for the re-creation of a soil atmosphere. Into these spaces will evaporate some water vapor and some of the dissolved gases from the soil solution, notably the carbon dioxide. As this last substance escapes from the solution to the atmosphere the equilibrium between the dissolved carbon dioxide or carbonic acid and the calcium hydrogen carbonate will be disturbed. This latter unstable salt will partially break down to liberate carbon dioxide and restore the equilibrium. At the same time will be formed some of the less soluble normal calcium carbonate, which will in consequence precipitate from the solution, coating the less soluble soil grains, more or less filling up the soil spaces, and modifying the texture and structure of the soil at that point.

The deposition of calcium carbonate at any point, having once commenced, probably facilitates further deposition at that same point for two reasons. While calcium hydrogen carbonate is, as stated above, to be regarded as an unstable compound in solutions in contact with an atmosphere containing less than a certain definite proportion of carbon dioxide characteristic for any given concentration of this salt, nevertheless, as Treadwell and Reuter have shown, an unstable con-

[1] In this connection, see paper by Dr. Cameron, elsewhere in this report.

[2] The maximum amount of calcium carbonate which can possibly be dissolved by water under the most favorable conditions is probably, as Dr. Cameron has pointed out elsewhere, very large, and has never been determined even approximately. Witness in this connection the large amounts of this substance found in waters from some subterranean springs, etc.

dition of equilibrium can be realized with this particular bicarbonate and a solution may be obtained containing an abnormal amount of this salt. In a somewhat special sense the solution may be regarded as supersaturated with respect to this salt. Dr. Cameron has shown that in all probability it is the bicarbonate of calcium and never the normal carbonate with which one has to deal in natural waters and ground solutions. By long standing, shaking, etc., or by coming in contact with solid calcium carbonate this unstable equilibrium is displaced, carbon dioxide is given off, and normal calcium carbonate precipitated. Thus, if supersaturated solutions of calcium hydrogen carbonate in the soil come in contact with a deposit of calcium carbonate, it may be expected that some of the dissolved salt will be promptly decomposed, with a further precipitation of the normal carbonate.

Again, as stated above, the deposition of calcium carbonate on the soil grains tends to modify the texture or structure of the soil; and it is in just such places of contact between soils of different texture that the escape of carbon dioxide from the soil solutions to soil atmosphere is probably most effective and, in consequence, the deposition of the normal calcium carbonate greatest.

It has been suggested by Mr. Means that the diurnal change in barometric pressure may play a considerable part in the deposition of lime carbonate hardpan in the soils of arid regions. According to this view an increase of barometric pressure will be accompanied by a forcing of the atmosphere above the soil down into the soil and a consequent dilution of the carbon dioxide in the soil atmosphere. Successive increases and decreases of the barometric pressure may be regarded as in effect actually pumping out the carbon dioxide in the upper portion of the soil. In the dry soils of arid regions this aeration process may be regarded as probably effective to depths of from 3 to 6 feet, and the consequent dilution of the carbon dioxide in the soil atmosphere accounts for the formation of the calcium carbonate hardpan at that general depth.

In many cases it is probable that the presence of other more soluble salts has had an important part in the formation of calcium carbonate hardpan. It has been shown by Cameron and Seidell[1] that the solubility of calcium carbonate in sodium sulphate solutions steadily increases with concentration of the latter salt, but that in sodium chloride solutions it rises to a maximum in a solution containing about 10 to 12 grams sodium chloride per liter, and as the concentration with respect to sodium chloride increases beyond this point the solubility of the calcium carbonate decreases.

Should the ground solution in its slow rise through the capillary spaces in the soil reach a concentration with respect to soluble chlo-

[1] See paper by Cameron, elsewhere in this report.

rides beyond that at which the maximum amount of calcium carbonate dissolves, this latter salt would commence to separate from the solution. The presence of much soluble sulphates in the solution would tend to retard this precipitation of solid calcium carbonate, although on the other hand the presence of calcium sulphate or gypsum would much hasten it.

It is a matter of common observation that the calcium carbonate hardpans containing gypsum or more soluble salts, and therefore presumably deposited in large measure from solutions containing much soluble material, are apt to be less compact and dense and more pervious to water and plant roots than lime carbonate hardpans, which are presumably deposited mainly by the loss of carbon dioxide from an aqueous solution of the bicarbonate of lime.

As the lime carbonate hardpan is formed it retards or cuts off the rise of the waters below it to supply the place of that which has evaporated from the surface of the soil. Thus the rise of alkali from the soil below is checked by the hardpan. The addition of water to the surface soil may carry the surface alkali quickly down and into or below the hardpan softened by the water. On the other hand, this softening of the hardpan may allow the escape of the salts in the soil beneath, by capillary action, before the hardpan has had time to dry out, harden, or become compact again, so the effect of added water becomes a most important matter in connection with hardpan and is dependent upon the special conditions that obtain in any given case, such as the texture of the soil, the compactness of the hardpan, the amount of water used, the amount of soluble salts in the lower soil layers, etc.

By some, the wet condition of the soil and the rise of alkali on irrigated land are attributed to the presence of this hardpan, but so far it has not been found sufficiently dense to be impervious to water, and can, therefore, have had very little if anything to do with the rise of the alkali and ground water. When kept wet it becomes soft, and is hardly noticeable, except for thé whitish color of the soil in that particular stratum, due to the abundance of lime. When dry it is very hard and difficult to dig, and is a serious obstacle in excavating ditches and post holes.

WATER SUPPLY.

The irrigation water supply for Weber County is exceptionally good, notwithstanding the fact that there is often a shortage in the water supply toward the close of the irrigation season. The chief source of the supply is from the Weber and Ogden rivers, with smaller amounts from North Ogden Canyon and from springs which occur along the base of the Wasatch Mountains. The district is also well supplied with flowing artesian wells, some of which are large enough to irrigate considerable land. The water from the many

wells, if properly utilized, would in the aggregate irrigate hundreds of acres, but as yet it is very little used for this purpose.

The following table, giving the estimated monthly discharge of the Weber and Ogden rivers above where the irrigation canals are taken out, is taken from F. H. Newell's report, Progress of Stream Measurements, published by the United States Geological Survey, 1889, and is based on measurements for the year 1898:

Estimated monthly discharge of Ogden and Weber rivers at Ogden and Uinta, respectively.

Month.	Mean discharge in second-feet.		Total in acre-feet.		Total for Weber and Ogden.	Precipitation in inches, 1898.
	Ogden.	Weber.	Ogden.	Weber.		
1898.						
January	65	271	3,997	16,663	20,660	1.47
February	79	320	4,387	17,772	22,159	.19
March	90	392	5,534	24,103	29,637	1.82
April	267	1,329	15,888	79,081	94,969	.37
May	297	1,606	18,262	98,750	117,012	5.23
June	102	752	6,069	44,747	50,816	.81
July	35	291	2,152	17,892	20,044	.00
August	33	92	2,029	5,657	7,686	.30
September	31	171	1,845	10,175	12,020	.30
October	32	302	1,968	18,569	20,537	1.47
November	32	439	1,904	26,122	28,026	1.12
December	32	416	1,968	25,579	27,547	.60
The year	91	532	66,006	385,110	451,113	13.68

Drainage area, 360 square miles, Ogden River.
Drainage area, 1,600 square miles, Weber River.

This table of discharge is for a year when the rainfall at Ogden was below the normal, and we will assume, therefore, that the figures here given are not greater than the normal discharge should be. It will be noticed from this table that about half of the annual discharge occurs during the two months of April and May, and this in spite of the fact that the mean monthly precipitation during this time is no greater than it is for the five preceding months. The precipitation for the preceding months, November to March, inclusive, especially in the mountains, is chiefly in the form of snow, and therefore does not find its way into the streams until it melts. It is during April and May that most of this snow melts, and hence the large discharge of the streams during that period. In Weber County there is little demand for irrigation water at other times than during the five months from May to September, inclusive.

It has been previously stated that the area of the district under irrigation probably does not exceed 40,000 acres. It will be of value, therefore, to compare this area with the water supply according to the table, and see what are the possibilities of increasing the area

of irrigated land. On the basis of 2½ acre-feet of water for each acre of land, which is usually considered a liberal allowance, 6 inches of water would be required for each of the five months from May to September, inclusive. On this basis we find that the combined water supply of the two rivers during May is sufficient to irrigate 234,000 acres, for June 102,000 acres, while in July it is sufficient for only 40,000 or just about present irrigated area. In August the supply is very low, and is only sufficient for 15,000 acres, or less than half of the present area. In September the water supply shows a slight rise, but is still inadequate for the present irrigated area. It is seen, therefore, that during the irrigation season there are two months when the water supply far exceeds the demand, one month when it is just sufficient, and two months when there is a shortage. Taking the five months, the total water supply is adequate to irrigate 83,000 acres, or twice the present area, and could the water supply for the whole year be saved it would be sufficient to irrigate 180,000 acres. This assumes no loss by evaporation and seepage during the transit of the water from the streams through canals and laterals to the land, a condition which is far from realized in practice. Loss from this source is not absolute nor permanent, since seepage usually plays the most important rôle, and waters escaping as seepage ultimately find their way, in part, back to the river beds and are again taken out by lower irrigation systems.

These figures bring out an important fact which has long been recognized by the more enterprising men of the community, that is, the necessity for some means of impounding the water that goes to waste just prior to and during the early part of the irrigation season, in order to tide over periods when the natural flow of the river is low, and in order also to increase the acreage under irrigation.

A large reservoir has already been constructed some distance up on the Weber River and a movement is in progress to construct another on the Ogden River. The water from both the Weber and Ogden rivers is of excellent quality for irrigation purposes, that is, it contains so small an amount of salts that it can be used with no fear of injuring the soils by stocking them with alkali, which sometimes occurs in the case of irrigation waters heavily charged with salts.

The following chemical analyses, made under the direction of Dr. Cameron, show the salts in samples of water taken from the Ogden River at Ogden and from the Weber River at the mouth of the Weber Canyon. These samples were taken in October, 1900, when the flow was quite low, but when it had increased slightly, due to recent rains. The samples no doubt show more salts than would be found in the early part of the irrigation season when the water supply is more abundant.

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Amount and kind of salts in river water.

Source of water.	Salts per 100,000 parts of water.	Percentage composition.							
		Ca.	Mg.	Na.	K.	SO_4.	Cl.	CO_3.	HCO_3.
Ogden River at Ogden..	44.4	12.16	4.50	8.56	3.15	4.28	17.58	2.03	47.74
Weber River at mouth of canyon............	45.5	13.40	4.62	6.16	3.08	6.81	10.11	3.96	51.86

Theoretical combination of acids and bases.

Source of water.	Percentage of combined salts.							
	$CaSO_4$.	$Ca(HCO_3)_2$.	$Mg(HCO_3)_2$.	$MgCl_2$.	KCl.	NaCl.	Na_2CO_3.	$NaHCO_3$.
Ogden River	5.86	42.80	....	17.56	5.86	2.93	3.60	21.39
Weber River.......	9.45	43.51	13.19	9.89	5.72	....	7.03	11.21

Water taken from the Plain City Canal near its terminus in September was found to contain 56 parts of salts in 100,000 parts of water, of which 36 parts were bicarbonates. Early in October similar determinations were made of the water in the Hooper Canal and in the Davis and Weber Counties Canal. The former contained 51 parts of salts, of which 40 parts were bicarbonates, and the latter 52 parts, of which 34 parts were bicarbonates. None of these determinations show any appreciable amount of carbonates.[1] Late in October the water at the mouth of Weber Canyon was found to contain 47 parts of salts, of which 34 parts were bicarbonates. In contradistinction to the other determinations, this one contained 3.7 parts of carbonates. These determinations show that on an average 70 per cent of the salts in the irrigation water occurs as bicarbonates. The analyses given above show that the salts in the water from the Ogden River contained 64.19 per cent of bicarbonates, while the salts in the water from the Weber River contained 67.91 per cent of bicarbonates. Lime is the most abundant of the bases, and upon combining the salts it gives about one-half of the total in the form of lime salts. Lime salts in irrigation waters when present as sulphates and carbonates are not harmful, but, on the contrary, lime in small amounts is stimulating to plant growth.

APPLICATION OF WATER.

The water supply is of good quality and abundant if the distribution could be controlled. There is great need for storage reservoirs in order to extend the present area of cultivated lands. This fact is realized by the people and is being acted upon by them. The canal systems are plentiful, but in order to increase the irrigated areas they

[1] This is due probably to the high degree of dilution of the salts and to the fact that these salts are mainly lime bicarbonate, which is shown in Cameron's paper (p. 431) to be very stable.

need enlargement and extension rather than the addition of new canals. Every additional canal offers a new avenue for the loss of water, and it is advisable to reduce the long canals to a minimum number. The main canals of the district aggregate, approximately, 130 miles in length, while the laterals probably aggregate considerably more than this. With this great length in canals and laterals, running for the most part over deep, sandy loam or sandy soils, the loss by leakage must be very great. No measurements were made to determine what this loss is, but it is probably fully half of the water that is taken into the head gates of all the canals. In other words, only half of the water taken into the canals reaches the fields to which it is to be applied. A realization of the enormous loss of valuable irrigation water from this source alone should insure far greater care in the location and construction of the main irrigation canals. This is an engineering problem, and where the soils are of such a character as to make it impossible to construct canals that will not lose large amounts of water by leakage the value of both water and land will often justify the expenditure of money for the construction of water-tight pipe lines or cement ditches to carry the water to the land without loss.

Another source of loss of irrigation water, especially in irrigating sandy lands, is from overirrigating or applying more water than the soil is capable of holding, a large part of it thus going into the drainage and doing no good to the irrigated crops. This loss by seepage from lands, as well as from canals, is not only a loss outright, but oftentimes damages either the land irrigated or other land lying at lower levels.

In the case of leaky canals, it is suggested that their sides and bottoms be puddled when in a wet condition by dragging with a plank, by driving sheep or goats through them, or by introducing waters charged with sediments which, upon settling, will fill the pores of the soil in the bottom of the canals.

In the case of irrigating sandy soils or sandy loams underlaid by gravel, it is advisable to run the water for short distances, quickly covering the surface in the case of the flooding method, and then turning the water to adjacent areas so soon as it has wet the soil to the requisite depth, which usually need not exceed 4 feet.

A study of the underground water map brings out the important fact that under the greater part of the irrigated lands the water table is within less than 6 feet of the surface. On account of this state of affairs too much stress can not be placed upon the necessity for great care in preventing a further rise of this ground water by further leakage from canals or from the overirrigation of lands. The advisability of State legislation to compel the ditch owners to guard against undue seepage and to prevent property owners from using excessive amounts of water in irrigation is sufficiently obvious to need no comment.

Property owners whose lands are thus damaged should be enabled to recover damages in the courts.

As a rule, the canals are the joint property of the owners of the irrigated land, each man having shares in proportion to the amount of land owned. Anyone not holding shares can rent water rights from those who own more shares than they have personal need of. The water is generally apportioned among the landowners in proportion to the stock they control. The exact amount of water used per acre in this district has not been determined, but the average for the State of Utah is estimated at about 1 second-foot for each 100 acres. There is generally an abundance of water in the canal, but when there is any deficiency all suffer alike in a reduced supply.

UNDERGROUND WATER.

The underground-water map shows the depth to standing water at the time the survey was made. Notwithstanding the fact that it was made during the driest part of one of the driest years on record, when both rainfall and the irrigation supply were very short, it shows that under a large portion of the district, ground water stands very close to the surface and that as the acreage of irrigated land increases greater care will need to be exercised to prevent a further rise of this ground-water table. Under about one-half of that portion of the district within the old shore line, the ground water was found at from only 3 to 6 feet below the surface, and in certain areas northwest of Ogden and near North Ogden, especially on the meadows and Jordan loam soil, it was found to be within less than 3 feet of the surface. None of the last-named areas are farmed, but are used chiefly as meadow land. While the shallow-rooted cereals, such as wheat, oats, barley, and the grasses, may do well with the ground water at only 3 feet from the surface, the deeper-rooted alfalfa and the fruits in general will not do at all well with the ground water so near the surface. If alkali is present it is almost certain to accumulate at the surface to such an extent as to prevent the growth of crops.

For alfalfa and the fruits the ground water should not be allowed nearer than within 4 feet of the surface, while for trees, especially the stone fruits, it should be even farther below the surface if good results are to be expected. There is great need of underdrainage for this class of lands. Money thus expended will bring sure and lasting returns, provided drainage is installed in a thorough and economical manner. This subject will be discussed in subsequent pages.

There is a large body of land between the Weber River and Little Mountain, under which the water table occurs at from 6 to 10 feet below the surface; but this land is as yet mostly in its virgin state, and if a large part of it should be brought under cultivation the water table would undoubtedly rise. The land is quite level and the lower depths of the soil are quite heavily charged with alkali. It is there-

fore incumbent upon the owners of this tract of land to guard against too great a rise in the ground water, in case a considerable part of this land is placed under irrigation, the probability of which is indicated by the present canal systems.

The large level area of recent lake-bottom soil usually has standing water at from 2 to 3 feet below the surface, becoming even less than this as the shore is approached.

ALKALI IN SOILS.

The following table gives the composition of the alkali in the crusts from a number of localities, as determined under the direction of Dr. Cameron of the laboratory of the Division of Soils:

Chemical composition of crusts from Weber County (percentage of bases and acids).

No.		Ca.	Mg.	Na.	K.	SO_4.	Cl.	CO_3.	HCO_3.
		P. ct.	P. ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per cent.
5027	Crust 5 miles west of Ogden	Tr.	Tr.	36.94	1.75	0.69	34.15	13.99	12.48
5028	Crust 2 miles north of Hooper	......	Tr.	35.73	2.30	8.73	15.99	21.65	15.60
5029	Crust 2 miles east of Hooper	Tr.	Tr.	35.80	3.30	10.05	46.89	2.44	1.52
5030	Crust 2 miles SW. of Plain City	Tr.	0.44	33.56	2.11	8.33	34.34	2.44	18.78
5031	Crust 5 miles SW. of Ogden	Tr.	Tr.	36.34	1.37	13.98	39.19	3.70	5.38
5032	Black alkali crust SW. of Hooper	Tr.	Tr.	36.78	.98	12.52	39.70	4.51	5.51
5033	Crust on lake bottom SW. of Hooper	0.36	1.01	34.96	2.37	6.09	54.87	....	.34
5034	Crust from escarpment SW. of Hooper	2.29	.95	31.63	2.55	17.32	44.72	....	.54
5035	Dark crust east of Hooper	Tr.	Tr.	34.58	3.99	11.69	35.15	7.63	6.96
	Mean	.30	.27	35.15	2.30	9.93	38.33	6.27	7.45

The theoretical percentage combination of the above analyses is given in the following table:

Theoretical percentage combination.

No.		Per cent soluble.	$CaSO_4$.	$MgSO_4$.	Na_2SO_4.	NaCl.	KCl.	Na_2CO_3.	$NaHCO_3$.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	P. ct.	Per ct.	Per cent.
5027	Crust 5 miles west of Ogden	25.55	....	....	1.02	53.72	3.34	24.74	17.18
5028	Crust 2 miles north of Hooper	26.40	....	....	12.90	22.95	4.38	38.28	21.49
5029	Crust 2 miles east of Hooper	34.21	....	....	14.90	72.41	6.29	4.31	2.09
5030	Crust 2 miles SW. of Plain City	1.80	....	1.44	10.76	53.72	4.00	4.33	25.75
5031	Crust 5 miles SW. of Ogden	8.18	....	....	20.67	62.62	2.61	6.77	7.33
5032	Black alkali crust SW. of Hooper	23.75	....	....	18.54	64.04	1.86	7.97	7.59
5033	Crust on lake bottom SW. of Hooper	42.58	1.21	5.00	1.83	86.98	4.51	....	.47
5034	Crust from escarpment SW. of Hooper	26.94	7.76	4.71	11.91	69.92	4.96	....	.74
5035	Dark crust east of Hooper	5.92	....	....	17.30	52.04	7.60	13.50	9.56
	Mean	....	1.00	1.24	12.20	59.83	4.39	11.10	10.24

It will be seen that sodium (Na) forms the chief part of the base elements, while chlorine (Cl) is chief among the acids. Since the

region where these crusts occur is near Great Salt Lake, which is known to contain large amounts of sodium chloride, it is not surprising to find these results. It is noticeable also that carbonic acid ions (CO_3) and hydrogen carbonate ions (HCO_3) form quite a percentage of the acids in seven out of the nine samples, and that in these seven samples both lime and magnesia are present only as a trace. In the remaining two samples both lime and magnesia are present in appreciable amounts, but the carbonate is absent, while bicarbonate occurs in very small amounts.

The following table shows the amount of salt in various depths of the soil and the percentage combination of the bases and acids theoretically combined. As here combined, it is found that on an average slightly more than 64 per cent of the salts occur as chlorides, of which common salt is the usual form. About 14.5 per cent occur as the sulphates, 11 per cent as carbonates, and the remainder as bicarbonates. Of these four classes of salts, the carbonates are by far the most destructive and, owing to their caustic properties, attack the tissues of plants and disintegrate them.

While alkali crusts collected from a number of widely separated points over a district have been taken as representing the composition of the alkali of the district, it had occurred to the writer that, owing to the absorptive power of the soil and the variation in the amounts of the different salts that go into solution when present in excess, there would probably be a variation in the character of the alkali from the surface downward. For this reason representative samples of alkali soils from various parts of the district were analyzed, under the direction of Dr. Cameron, the samples being usually in sets of three, representing the first, third, and fifth foot in depth.

The following table shows the results of these analyses:

Chemical composition of alkali in the soil at different depths.

No.	Depth.	Locality.	Per cent soluble.	Ca.	Mg.	Na.	K.	SO_4.	Cl.	CO_3.	HCO_3.
	Ft.		*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
5036	1	N. C. sec. 36, T. 6 N., R. 2 W	0.96	0.21	0.41	28.01	5.39	5.39	18.87	4.36	37.36
5037	3	.....do	.59	10.51	.68	18.65	2.71	4.74	16.62	7.12	38.97
5038	5	.....do	1.48	3.37	.81	26.96	3.37	6.06	28.44	3.23	27.76
5039	1	N. C. sec. 23, T. 7 N., R. 2 W	3.30	2.67	Tr.	31.62	5.45	1.21	55.42	......	3.63
5040	1	S. E. C. sec. 16, T. 7 N., R. 2 W	.82	5.84	.24	24.82	6.33	2.43	42.82	.73	16.79
5041	3	.....do	.99	5.46	......	26.26	4.44	1.41	39.19	......	23.24
5042	5	.....do	1.08	2.96	Tr.	29.08	7.04	1.67	47.59	Tr.	11.66
5044	3	¼ E. of C., sec. 5, T. 6 N., R. 3 W	1.06	7.37	1.32	24.02	3.21	3.21	37.99	5.67	17.21
5045	5	.....do	1.43	.98	Tr.	34.08	2.93	2.66	43.71	4.19	11.45
5053	1	C. of S. W. ¼, sec. 24, T. 5 N., R. 3 W	1.30	11.85	Tr.	20.31	2.46	2.15	28.77	7.38	27.08
5054	3	.....do	.90	8.03	.45	24.34	1.34	2.45	19.65	12.27	31.47
5055	5	.....do	1.27	2.20	.47	30.82	4.09	2.04	30.97	11.80	17.61
5062	1	¼ W. of N. E. C., sec. 16, T. 5 N., R. 2 W	2.14	3.65	.65	25.42	4.02	5.79	24.30	7.01	29.16
		Mean	......	5.01	.39	26.49	4.06	3.17	33.41	4.90	22.57

In the following table is given the theoretical percentage combination of the above analyses:

Theoretical percentage combination.

No.	Depth.	$Ca(HCO_3)_2$.	$CaSO_4$.	$MgSO_4$.	Na_2SO_4.	$CaCl_2$.	$MgCl_2$.	$NaCl$.	KCl.	Na_2CO_3.	$NaHCO_3$.	$Mg(HCO_3)_2$.
	Ft.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
5036	1	....	0.62	2.07	4.97	....	....	23.24	10.16	7.68	51.46	....
5037	3	34.24	6.78	....	....	....	....	23.73	5.08	12.54	13.90	3.78
5038	5	....	8.49	....	....	2.56	8.10	35.59	6.33	5.66	88.27	....
5039	1	....	1.70	....	....	6.06	....	76.92	10.35	....	4.97	....
5040	1	19.71	3.40	....	....	....	....	61.82	11.92	1.46	....	2.19
5041	3	....	2.02	....	....	13.33	....	44.84	7.88	....	31.93	....
5042	5	....	2.78	....	....	5.00	....	62.97	18.33	....	15.92	....
5044	3	....	4.53	....	....	16.61	5.09	34.15	6.04	10.00	23.58	....
5045	5	....	3.63	....	....	....	....	67.74	5.59	7.40	15.64	....
5053	1	....	2.92	....	....	30.76	....	11.39	4.62	13.08	37.23	....
5054	3	28.79	3.35	....	....	....	....	30.59	11.92	21.65	10.49	2.68
5055	5	....	2.83	....	....	3.77	1.89	38.85	7.70	20.75	24.21	....
5062	1	....	8.13	....	....	3.55	2.52	25.70	7.66	12.34	40.10	....
		6.36	3.94	.16	.37	6.28	.97	41.31	8.35	8.66	23.67	.66

In comparing this table with the table of the crusts, it is seen, in regard to the bases, that lime is always present in the soil alkali in appreciable amounts, whereas in the crusts it is usually absent. Another fact in regard to lime is that it is usually most abundant in the third foot, the mean of the first, third, and fifth foot samples being 4.84, 8.34, and 2.38 per cent, respectively. The mean of the thirteen determinations gives 5.01 per cent, or about seventeen times as much as occurs in the mean of nine crusts. Comparing the lime salts of the crusts and soils as combined on the lower part of each table, we have 1 per cent of it in the former to 16.6 in the latter.

Potash also forms a slightly larger percentage of the soil alkali than of the crusts, while soda, as might be expected, is most abundant in the crusts.

Upon comparing the acids of the crusts and soils quite marked differences occur. While chlorine (Cl) predominates in both the soil and crusts, yet it is more abundant in the latter. In regard to the sulphions (SO_4), there is more than three times the percentage in the crusts than occurs in the soil, while for bicarbonates (HCO_3) the reverse relation is true in about the same proportion. The carbonic acid ions (CO_3) are slightly more abundant in the crusts than in the soils, but do not show any marked tendency to accumulate in the crusts or upper layers of soil, although the view that they do is held by some.

The relation between the carbonates and the bicarbonates shows a ratio of about 1 to 1 in the crusts, while in the soil it is about 1 to 5. This seems to be largely a function of the concentration of the solution, the ratio between the carbonates and bicarbonates increasing with the decreasing concentration of the solution. It seems, there-

fore, that where crusts are forming at the surface of the soil through the combined agencies of capillarity and evaporation the chlorides and sulphates of soda form in greater proportions than they previously existed in the soil, while calcium remains almost entirely in the soil. The carbonates also show a slight tendency to accumulate in the crusts, while the bicarbonates show a reverse tendency.

The amount of alkali present in the soils and irrigation waters was determined by the electrical method. The chlorides, carbonates, and the bicarbonates were determined by a volumetric method recently devised for rapid field work. In the soil the percentage of alkali was determined in the first, third, and fifth foot in depth and the mean of these three determinations taken as the salt content of the upper five feet of soil. The alkali map represents what may be considered the average conditions of the various areas at the time the survey was made. If the upper foot was free from alkali and the third and fifth foot showed large amounts, the soil was classed according to the average of the three determinations. With such an arrangement or distribution of the salts, which frequently occurs in virgin soils, a crop might be started in excellent shape, or perhaps brought safely to maturity, but with a few irrigations the salts would rise to the surface unless excellent underdrainage was present or was provided for, and the land would become unfit for cultivation.

The alkali map brings out the fact that the uplands are usually free from injurious amounts of alkali; the intermediate lands are often mildly charged with it; while the lower and more level areas near the lake nearly always contain very large amounts. The lake is undoubtedly responsible for the salty condition of the last-named lands, for its waters have covered much of this land within comparatively recent years.

There is a general agreement between the soil and alkali maps, and to some extent between the alkali and ground-water maps. As a rule, the heavier soils carry most alkali, while the sandy soils are least troubled with it. Areas on the ground-water map, with water 10 or more feet in depth, are always free from injurious amounts of alkali. Wherever the water table is within 3 feet or less of the surface for a portion of the season, and alkali salts are present, these will always be found concentrated immediately at or near the ground surface. With the water table 4 feet or more below the surface the surface foot will usually be comparatively free from alkali and the maximum amount of alkali will occur usually about 1 foot above the water table, providing it be not more than 10 feet below the surface.

The above table of chemical analyses of crusts, collected from various parts of the district, shows only two crusts in which sodium carbonate (black alkali) exceeds 20 per cent of the salts present, and an average of them all gives 11.1 per cent of the salts as sodium car-

bonate. The table giving the composition of the salts in the soils, on page 230, shows two of the samples which contain slightly more than 20 per cent of the total salts in the form of black alkali, while the mean of thirteen determinations shows only 8.66 per cent of it to exist as such.

The mean of a large number of field determinations show that 15 per cent of the alkali in the surface foot of soil is present as carbonates.

The limit of endurance by plants for black alkali is placed at 0.1 per cent, while for white alkali it is placed at 0.5 per cent. We see, therefore, that where we have an excess of black alkali we will generally have also an excess of total salts; and to convert the black alkali to the white by the application of gypsum would be a waste of time and money, for there would still remain an excess of alkali which must be removed before the land could be profitably farmed.

A number of factors enter into the question of the limit of endurance of plants for alkali. It has been brought out that the different crops withstand different amounts, and that with the same amount of alkali plants suffer less in heavy soils than in sandy ones. The more sandy a soil the lower its water-holding capacity, and with a given percentage of salts in the soil the less the percentage of soil moisture and the more concentrated it must be with reference to the salts. It is the concentration of the soil moisture from which the plant has to draw its supply of mineral food that determines the limit of endurance for the plant, rather than the percentage of salts in the soil. The kind of salt, also, has an effect, sodium chloride, percentage comparison, being more harmful than sodium sulphate. Of the relative harmfulness of the different salts for plants, comparatively little is known. This is a subject that demands fuller investigation by the vegetable physiologist.

BLACK ALKALI.

The corrosive sodium carbonate, while forming a considerable part of the alkali salts of the district, seldom exceeds 0.1 per cent without the presence also of an excess of total salts. There are a few areas, however, notably about the towns of Plain City and Hooper, where the black alkali is the chief menace to agricultural progress. In such localities the black alkali, varying in amounts from 0.05 to 0.1 per cent of the soil and over, is shown on the alkali map by two sets of diagonal lines. Where present in amounts varying from 0.05 to 0.1 per cent it is equally as harmful as 0.2 to 0.4 per cent of total salt, and will result in spotted fields. In amounts which exceed 0.1 per cent it is considered fatal to plants. By the application of gypsum it is largely converted to the less harmful white alkali if the soil is well aerated and drained. Where this form of alkali is the source of trouble and where gypsum can be obtained at a cost not too great, it will be advisable to

apply gypsum to the surface of the soil in a finely divided state and to incorporate it with the soil by cultivation and irrigation.

For the conversion of 0.1 per cent of black alkali into white alkali about 3½ tons of gypsum for each acre-foot will be required. If there is no rise in the salts, however, it seems probable that only a correction for the first foot in depth would be necessary, since it is at the surface of the ground that the damage from this form of alkali is nearly always observed.

There seems to be little tendency for the black alkali to accumulate at the surface of the soil in a ratio greater than other forms of alkali, and it occurs at all depths the same as any of the salts.

MAPS.

The maps, three in number, which accompany this report are on the scale of 1 inch to a mile, and show the prevailing conditions at the time of the survey, September to October, 1900, for all areas not smaller than 10 acres in extent. Since areas smaller than 10 acres would represent less than one sixty-fourth of a square inch on the map, there is little justification for doing the work in greater detail. The best base maps of the district were obtained from the county officials. These maps gave the section lines, the roads, railroads, rivers, mountains, and the principal towns, and were used as base maps for the soil work. In some instances the location of these features on the map were not correct, and in such cases, notably the river, which changes its course from time to time, changes were made. This is also true in regard to the location of the base of the mountains and of the railroads. The greatest change made on the maps in this respect was the moving of the lake shore line westward, a distance varying from 2 to 11 miles, in order to conform with the present lake shore line.

The location and course of the principal canals were accurately mapped as the regular field work progressed, also the escarpments, hills, and the base of the mountains.

The soil map shows the exact location and extent of the various types of soil which are described in these pages. It has been the endeavor of the author to make the description of these soil types both valuable and practical to the farmer by bringing out what crops are best adapted to the soils and what dangers to guard against in irrigation in order to prevent damage and undue loss of water.

The alkali map shows the distribution of the alkali, and should be of especial value in reference to the virgin soils as showing which are sufficiently free from alkali to produce crops as well as those that will have to be reclaimed before crops can be grown. It shows, in different colors, the mean percentage of salt in the upper 5 feet of soil, the intervals represented by the different colors being 0.0 to 0.2, 0.2 to

0.4, 0.4 to 0.6, 0.6 to 1, 1 to 3, and 3 per cent, calculated on the dry weight of the soil.

Leaving out of consideration the lake bottom land, all of which contains more than 3 per cent of alkali and none of which may be considered fit for any agricultural purpose for some time to come, there remains about 137,000 acres of land, the greater part of which is so situated that it could be irrigated and which, when reclaimed and irrigated, is destined to become valuable agricultural land. Of this portion, about 83,000 acres contain less than 0.2 per cent of alkali and may be considered perfectly safe for farm crops so far as trouble from alkali is concerned. The areas containing from 0.2 to 0.4 per cent of alkali aggregate 16,000 acres, and, while some portions of these areas are cultivated with a moderate degree of success, it is usual to find the field containing spots where the crops fail even under the most favorable conditions. As the lower limit of this range in salt content is approached, the conditions may be quite favorable, especially if the greater part of the salts are below the second foot in depth, but as the upper limit is approached partial to complete failure in the crops is usual. This, however, does not depend upon the salts alone, for, with good drainage, upon applying irrigation water the salts move downward and the conditions rapidly improve, while with poor drainage the salts come to the surface and often destroy the entire crop.

All areas containing from 0.4 to 0.6 per cent of alkali, aggregating 7,000 acres, are unfit for any of our agricultural or horticultural crops. There is one exception to this, namely, in the case of a virgin soil having the salts mostly below the second foot in depth. In such cases, if good natural drainage is present or artificial drainage is provided, the process of reclamation may begin by putting in shallow-rooted crops, such as wheat, oats, or barley, and by liberal applications of water the salts will move further downward so that in succeeding years deep-rooted crops can be grown.

The process of reclamation requires frequent and liberal application of water in order to wash out the excess of alkali, and since barley is more resistant of both alkali and water than wheat or oats, it is recommended as the best crop to use in this connection.

The areas containing from 0.6 to 1 per cent of alkali aggregate 13,000 acres; those with 1 to 3 per cent, 11,500 acres; and those with more than 3 per cent, about 2,500 acres. All of these areas are too salty for any kind of farming, but when sufficiently moist they maintain a native growth of salt grass which makes fair pasture, and on the drier parts there is usually a considerable growth of greasewood (*Sarcobatus virmiculatus*) and other salt-loving plants on which sheep feed during the winter months. The income from this source, however, is very small.

The aggregate of the above areas, containing from 0.2 to more than 3 per cent of alkali, amounts to 50,000 acres. Besides this, there is

nearly 60,000 acres of lake bottom soils, all of which contain more than 3 per cent of alkali, the average probably being near 10 per cent. This makes a total of 110,000 acres of alkali land, or somewhat more than one-half of the entire district.

Besides the map showing the total alkali, there was also constructed a black-alkali map. It was found, however, that there were only a few localities in which the corrosive black alkali was in excess that there was not also an excess of total salts. As a consequence of this, the black alkali, when present in amounts from .05 to 0.1 per cent and above 0.1 per cent, is shown on the alkali map by two sets of diagonal lines only on the areas having less than 0.4 per cent of total salts. Such areas are noticeable in the vicinity of Hooper and Plain City.

The ground-water map shows the depth to standing water at intervals of 0 to 3, 3 to 6, 6 to 10, and more than 10 feet below the surface. The map is believed to be of especial value as indicating areas that are in need of immediate drainage, as well as areas where great care should be exercised in the application of irrigation water in order to prevent a further rise in the water table. As previously stated, this map shows the condition in the driest part of one of the driest years on record, and therefore shows the ground water slightly lower than it usually is.

All areas with water within 3 feet or less of the surface are in immediate need of drainage if the productive power of the land is to be increased.

Not all of the lands with the water table within 3 to 6 feet of the surface are in need of drainage at present, but a considerable percentage of such do need drainage, and this is especially true if the water table rises to within 4 feet of the surface during the irrigation season.

Lands with water at 6 feet or more below the surface are in no need of drainage so long as this condition can be maintained. With the water table 6 to 10 feet below the surface under level virgin land, there is danger of a marked rise in the table when such lands are irrigated, and it will often be advisable to provide for this contingency by underdrainage, even before the practice of irrigation begins.

RECLAMATION AND UTILIZATION OF WASTE LANDS.

The foregoing pages and the accompanying maps show the types of soils and their condition with reference to alkali and ground water; also the nature, quality, and supply of irrigation water for the whole district. Let us next consider the practical problem, how best to utilize these resources.

It is of course recognized that the justification for investing capital in the improvement of lands depends not alone upon their character and available water supply, but also upon their location with reference to civilization, markets, and transportation facilities. In other

words, it resolves itself into a business proposition, in which the expense is justified only so far as it will ultimately bring profitable returns from the investment.

The Ogden district is perhaps the most important one in the State. Ogden, with a population of about 20,000, is an important business center. It is the largest city in the district and the second largest in the State, as well as being the most important railroad center between Denver and San Francisco. It is the terminus of three great western railway systems, namely, the Union Pacific, the Southern Pacific, and the Rio Grande Western. From it also the Ogden Short Line extends southward to the southern boundary of the State and northward into Idaho, Montana, Oregon, and finally to the Pacific Ocean. These facilities, together with the intensive form of agriculture and horticulture, the many canning factories, and the beet-sugar factory, make the justification for the investment of capital in the reclamation of lands perhaps greater than in any other section of Utah. Probably nowhere in the State will so large a percentage of the better lands be so well adapted to the production of fruit and truck crops as here. Lands in orchards of peaches and pears, with trees coming into bearing, have a valuation as great as $1,000 per acre, and during the present season many such orchards have netted an income of 10 per cent on such valuation. Good truck lands in the immediate vicinity of Ogden have a valuation as great as $500 per acre, and some of them command an annual rental of $50 per acre for that purpose.

There is an abundance of land farther from the city which, on account of its condition, has little more than a nominal value. If drained and freed of its injurious amounts of alkali it would be equally as productive as the land near the city having a valuation of $500 an acre. Deducting a liberal percentage on the above valuation, because of the less desirable location of the land, the value when reclaimed should still be such as to make its reclamation a very inviting proposition for capital.

The estimated cost of reclamation by means of underdrainage is about $20 an acre. Allowing $10 for the water right, the whole cost, exclusive of the first cost of the land, would be about $30 an acre. On this basis it is a proposition not for the poor man but for capital, or for the man who owns such lands free of encumbrance and has an outside means of livelihood. For those who are willing to wait a few years for their returns such improvements will be found paying investments. The cost of bringing these lands to a high state of cultivation, including interest on the money expended, will not equal half of the above valuation on the best truck and orchard lands. Areas in excellent condition, which are especially well adapted to the growing of tomatoes, have a valuation far greater than their first cost plus water right, the cost of all improvements, and interest on the same. Nor

are such values fictitious; for a yield of 10 tons per acre, which brings from $8 to $10 per ton at the factories, is common. This gives a gross income of from $80 to $100 per acre, of which one-half should cover the total expense of production and marketing, leaving from $40 to $50 per acre as a net profit, or 10 per cent income on a valuation of from $400 to $500 per acre for the land.

This type of agriculture not only gives employment to much labor on the farms, but also affords occupation for many hands in the factories, as brought out by the following from The Industrial Utah:

> There are at present 1,000 hands employed in the canning factories in Weber County. Many of the employees are boys and girls in their teens, and will make enough during the canning season to pay for their books and clothing for the school year. The wages paid by the factories are very satisfactory, much of the labor being paid by the piece, or so much for a given amount of tomatoes or fruit handled by each person. Some young ladies earn as much as $2 per day, while numerous ones receive from 75 cents to $1.50. In addition to the enormous sum paid out in wages, the factories are of untold value for the lessons of thrift and industry they teach.

The output of canned tomatoes from the factories in Weber County during 1900 was approximately 200,000 crates of 24 quart cans each. These were disposed of at from $1.50 to $1.75 per crate, making the total income from this source slightly more than $300,000. Besides this, there were small amounts of peaches, pears, and small fruits canned. This industry is still in its infancy, and by the production of other truck crops suitable for canning—such as peas, beans, rhubarb, asparagus, etc.—the canneries might be much enlarged and their season of operation lengthened with great profit to both the operators and the producers.

It is obviously unnecessary to go into a lengthy and detailed discussion of the commercial advantages offered here. Enough has been said to set forth the advantages offered for the investment of capital in the reclamation and utilization of what are practically waste lands. Such investments, while void of the manifold returns occasionally realized by investors in mining stocks, are also free of the great elements of chance which the latter possess. Having secured a water right for the land and reached a decision as to its crop adaptation, the process of reclamation and improvement can proceed along intelligent lines. Crop adaptation will include the profitable disposal of the products. It would be folly to grow large areas of such a perishable product as strawberries when there would be no suitable market in which to dispose of them.

When lands are strongly impregnated with alkali and possess poor natural drainage, tile drainage should be supplied at the outset, in order to provide for the escape of the salts and to prevent their rise to the ground surface. Lands which are by nature wet will obviously need drainage. Tile drainage requires good outlets, which should be provided at the beginning by the community as a drainage district,

each individual landowner contributing to the cost of the same according to the benefits derived as decided upon by a board of disinterested arbitrators.

This means of drainage, of which but little is known in the irrigation districts, has been resorted to throughout the humid regions of the United States and has everywhere proved preeminently successful. While in the experimental stage in California, this system is being recommended for the reclamation of alkali lands by the California experiment station. It is also being tried in Utah, as shown by the following extract from Industrial Utah:

> One of the most striking illustrations of the benefit of drainage is shown on the farm connected with the State Insane Asylum. A tract of about 20 acres that had formerly been excellent farming and pasture land had in recent years, through seepage from a canal above, become a veritable swamp, too wet to even admit of pasturage of cows during the irrigation season. Last fall there was put in 1,500 feet of 3-inch drain tile, consisting of one main line and two laterals. The effect on the land is most remarkable, the soil turning up and pulverizing admirably through plowing this spring. The plot in question forms an object lesson that should be fruitful of results throughout Utah County.

The alkali and ground-water maps which accompany this report should be very useful in deciding what lands are in need of drainage and what are their conditions as regards the presence of alkali. In many instances much labor and money have been spent in the preparation and seeding of land to alfalfa and other crops when the soil was too salty to permit the seeds to germinate. In this respect the alkali map should be of special economic value in showing what lands are incapable of producing crops until the salt content has been reduced.

The areas showing more than 0.4 per cent of alkali are unsafe to seed to alfalfa. Even on the areas showing from 0.2 to 0.4 per cent of alkali there is a risk, especially if the salts show a tendency to accumulate at the surface. With the salts mostly below the second foot success in a moderate degree may be attained. The plants, when once well established, will withstand much more alkali than when in their infancy.

The alkali map shows the mean percentage of the alkali in the upper 5 feet of soil, but shows nothing as to its vertical distribution. Upon this point good judgment is required by the farmer. In general, when crusts are present upon the ground surface the maximum amount of salts occurs in the first foot, and when crusts are absent the maximum amount will not occur nearer to the surface than 3 feet and more often at a greater depth. Greasewood, shad scale, and sage bushes indicate an increase of salts with an increase in depth. Greasewood also indicates high alkali content, while sage indicates a comparatively low content. Salt grass indicates the maximum salt content near the surface.

In reclaiming alkali lands good judgment on the part of the farmer

will be required to decide when the process has gone far enough to make it safe to plant crops. There is a great need of men who have the training, facilities, and experience to decide upon just such points. A few men possessing the requisite knowledge locating in the principal irrigation centers could be of inestimable value, and their services should be sought and paid for in a manner commensurate with their value. Trained engineers are employed at high salaries by railroads, mines, and various other corporations, and men possessing the requisite training and experience to give advice and render expert services in regard to agricultural and irrigation problems should be in equally as great demand. If such services could be obtained, large sums of money could often be saved by the farmers and the farmers in turn could well afford to pay for them.

In the case of land at present farmed, good cultivation is essential. This is especially true for all fruit and hoed crops and doubly so when there is any tendency for the alkali to rise and accumulate at the ground surface. Frequent cultivation keeps the ground covered with a loose soil mulch, which reduces capillarity and the consequent loss of water from the surface as well as its resulting tendency to accumulate the salts there. Very salty lands that are not to be reclaimed can often be utilized by seeding to some species of salt-resisting plants, as the Australian saltbush, which has been tried in California and has been found to withstand large amounts of salt and yet be able to furnish considerable low-grade forage for stock.

DRAINAGE.

As previously stated, there are about 50,000 acres of alkali land in the district, which contain 0.2 per cent or more of alkali, exclusive of the lake-bottom soils, which are all very salty. This land is valued, according to its character and location, at from $5 to $40 per acre, or an average valuation of about $20, but taken as a whole it does not bring an income of 5 per cent on such a valuation. If reclaimed and a good water right secured, its value should not be less than an average of $100 per acre, or a total of $5,000,000, as compared with the present valuation of $1,000,000. Considerable of this land has a water right and is located under present canal systems. While there is not enough water for all of it under the present management, it is possible by storage to supply the needed water.

In a few areas of limited extent black alkali is the source of trouble, and while such areas can be reclaimed by the application of gypsum, it is not improbable that this process would cost more than to remove the salts by drainage. For the greater part of the area drainage is the only resource for reclamation. Owing to the sandy and pervious character of the soils of the district, tile drains will be very effective when at a considerable distance apart, and the cost of the tiles at Ogden should not exceed $5 per acre. The excavating, laying, and

covering of the tiles should not exceed $10 per acre, while $5 per acre should easily secure the outlets, which will usually be in the form of large open ditches or canals, constructed at the expense of the community. This makes the total cost $20 per acre, as previously estimated.

In the Mississippi Valley and in the East generally the usual depth at which to place tiles is about 3 feet, and the results thus obtained are usually quite satisfactory. The soil conditions in the East are quite different from those in the West. In the East the soils are usually closely underlaid by subsoils which are of such a nature that water moves through them slowly and the roots of plants penetrate them very little. In the West the soils are of uniform texture, the crops grown are usually deep rooted, and the climate is such that the roots keep well below the surface in order to escape the effect of drought.

Tile drains lower the water table only to their own level, and, as previously stated, where the water table is within 3 feet of the surface there will usually occur a concentration of the salts at the surface. In view of these facts, tiles should be placed at least 4 feet in depth for the irrigation districts in order to insure good drainage, and for orchards 5 feet will undoubtedly be better. In the absence of alkali, 3 feet in depth will be sufficient for the cereals, but this is not sufficiently deep for alfalfa, which is the chief forage crop of all our arid regions. Deeply laid drains are more efficient than shallow ones. The water continues to flow in them for a longer period of time, and their lateral influence extends further. The deeper the drains are laid, the greater can be the distance between them. This lessens the amount of tile and reduces the length of trenches to be excavated, which will fully counterbalance the extra expense of deeper excavation.

The size of tiles to use will depend upon the area which each line is required to drain, the maximum depth of water to be removed in a given time, and the fall which the line has. A 4-inch tile, when laid with a grade of 1 to 1,000 and required to remove one-half inch of water in twenty-four hours, will drain about 7½ acres. This should be sufficient for reclamation purposes; and in the case of ordinary wet areas, caused by seepage or overirrigation, a 4-inch tile should drain about 15 acres. To double the grade or fall in a line of pipe increases the rate of discharge about 30 per cent. While the cross sections of pipes vary according to the square of their respective diameters, the increase in discharge by increasing the size exceeds this by a large percentage on account of the comparative reduction in friction on the pipes; for example, if a 4-inch pipe will drain 15 acres, a 6-inch one will drain 46 acres, while an 8-inch one will drain about 104 acres.

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For more detailed information on drainage, the reader is referred to Farmers' Bulletin No. 40 of the United States Department of Agriculture, entitled Farm Drainage, which treats on drainage for the humid climate, but which will for the most part be practical for the irrigation districts also.

For good drainage good outlets are imperative. The size and depth of drains should be adequate to remove the water to a sufficient depth and within a comparatively short time. The grades along the lines of drain should be uniform and free from low places in which water and consequently sediment may settle. Laterals connecting with mains should do so at an angle considerably less than 90 degrees, the angle opening upstream.

Acknowledgments are due to Mr. L. B. Adams, of Ogden, who very courteously drove over the district with the field party at the outset; also to Mr. Bostaph, county surveyor, who kindly furnished base maps of the district. The Oregon Short Line Railroad furnished transportation, which was of material assistance in the work.

SOIL SURVEY IN THE SEVIER VALLEY, UTAH.

By FRANK D. GARDNER and CHARLES A. JENSEN.

INTRODUCTION.

The area surveyed, about 220 square miles, is located just south of the center of Utah, in the counties of Sevier and Sanpete. It begins at the town of Joseph, where the valley is quite narrow, and extends in a general northeasterly direction for 45 miles to the town of Gunnison, where the valley attains its maximum width. This portion of the valley, having an average width of 5 miles, is bounded on both the east and west by prominent mountain ranges which rise quite abruptly from the usually level floor of the valley. The altitude of the valley varies from 5,300 feet at Joseph to about 5,000 feet at Gunnison, while the adjacent mountains rise from 2,000 to 6,000 feet higher. South from Joseph the valley is quite narrow and there is very little land suitable for agriculture. North from Gunnison the valley maintains a width of two or more miles for some distance, but the land is so salty and the water supply so scanty and poor that very little has been done there agriculturally. (Fig. 20.)

At Gunnison the Sevier River is joined by the San Pitch River, and northeast of Gunnison is situated the San Pitch Valley, in which are a number of prosperous towns and a considerable area of good farming land.

The adjacent mountain ranges running parallel with the valley are cut in many places by canyons, more or less prominent, through which enter small streams, some of which are perennial and others intermittent. The perennial streams are all on the east side, and in the aggregate they furnish sufficient water to irrigate several thousand acres of land. All of the streams on the west side are dry for the greater part of the year, but in times of freshets they become veritable mountain torrents.

These canyons, with their freshly eroded and precipitous sides, are exceedingly interesting and furnish excellent opportunity for geologic study. Vast beds of rock salt, networks of pure gypsum, and sedimentary lime and sandstones, with myriads of imbedded marine shells, all tell a story of a former geologic age when these mountains were submerged beneath the sea. Here is told in nature's language, which needs no embellishment, the story of mighty eruptions that took place in past ages. Lava flows, igneous rocks, and faults that

are measured by thousands of feet expose rocks and formations of almost every known geologic age.

Although this portion of the Sevier Valley is supposed to be above the Bonneville beds, yet the elevation at Gunnison and vicinity is such that it is not impossible that the water of that ancient lake when

FIG. 20.—Sketch map of Utah, showing areas surveyed.

at its highest stage may have reached into this portion of the valley. There is good evidence of shore lines low down on the base of the mountains in this vicinity, which, however, may have been formed by a local lake.

The Joseph district was undoubtedly a small lake, caused by a dam across the valley at its narrowest place between Joseph and Elsinore. Dams of this kind are known to be common and are caused by the débris brought down by a side stream, which is deposited in the bed of the larger stream, thus causing a lake to occur back of it.

The adjacent mountains abound in all kinds of mineral wealth. Gypsum, salt, alum, coal, lead, copper, and gold are all known to exist in workable amounts, but as yet the mining industry has been but little developed. At Sterling, 6 miles northeast of Gunnison, coal is being successfully mined; and to the south of Elsinore are several gold mines that are being successfully operated. In the vicinity of Salina are extensive beds of rock salt of remarkable purity, which as yet are utilized only for stock salt and to some extent for the home demands. With cheap transportation this material could be profitably put on the market.

The Monroe Hot Springs, just north of the town of that name, are worthy of notice. If they were on the outskirts of one of our chief cities they would be worth a large fortune. From these springs flow about 200 gallons of water per minute, the water having a mean temperature of 150° F., and being mildly charged with salts, especially salts of lime, magnesia, potash, and soda. A small bath house is constructed there which is patronized by the people of the neighborhood. The water is said to have effected some remarkable cures, and is certainly pleasant to bathe in. At a very moderate expense the water of these springs could be piped into the houses of Monroe and utilized for baths, and perhaps for heating and other purposes. On another page is given the analysis of this water for irrigation purposes.

In the larger mountain passes a considerable growth of pine which furnishes good timber is found. On the higher mountains the winter's snow lingers during the greater part of the summer, and, together with numerous springs, furnishes a limited supply of water through the summer. This constant water supply, entering the valley by way of small canyons, affords excellent opportunity for developing water power. From this source could be generated sufficient electricity to furnish light and power for all the towns in the valley. Electric lights, city waterworks, and telephones are conveniences which enterprising towns throughout the West generally have, and these improvements greatly add to the comfort and convenience of any community. The towns of the Sevier Valley can obtain these improvements cheaply, and they will prove good investments.

Until recently the railroad facilities of the valley have been very poor, but the Rio Grande Western has now extended its line to Marysville, and will push still farther south. This affords an outlet for the products of the valley, furnishes a means of getting provisions from other localities, and brings the people into closer relation with other parts of the country.

The mountains and plateaus adjacent furnish summer range for thousand of sheep, which during the winter are brought into the valleys and fed with the crops of alfalfa and grain.

Monthly and annual precipitation from 1897 to 1900, also the mean for ten years' record, Richfield, Utah.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1897	1.00	1.85	1.95	0.12	0.06	0	0.04	0.25	1.45	1.59	......	0.40	8.71
1898	.70	.30	.40	.15	1.20	1	.40	.35	0	0	0	Tr.	4.50
1899	.30	.55	4.65	.70	Tr.	.14	.16	.12	.07	.38	.20	1.05	8.32
1900	.45	.20	0	.60	.08	Tr.	0	.07	.07	.05	.30	0	1.82
Mean for 10 years	.76	.91	1.64	.78	.38	.41	.49	.86	.66	.51	.16	.88	8.44

The climate is distinctly arid, the annual rainfall at Richfield being only 8.44 inches, as shown by the mean of ten years' record kept by

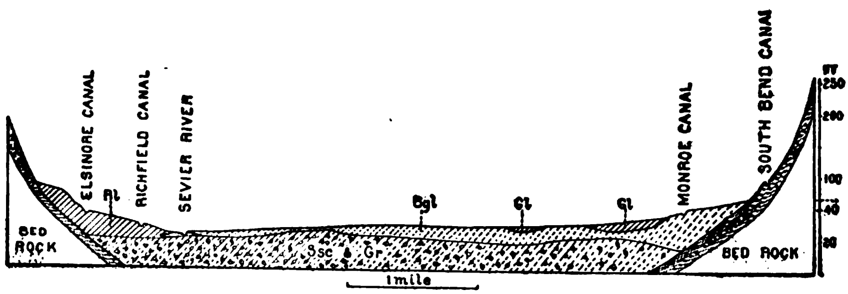


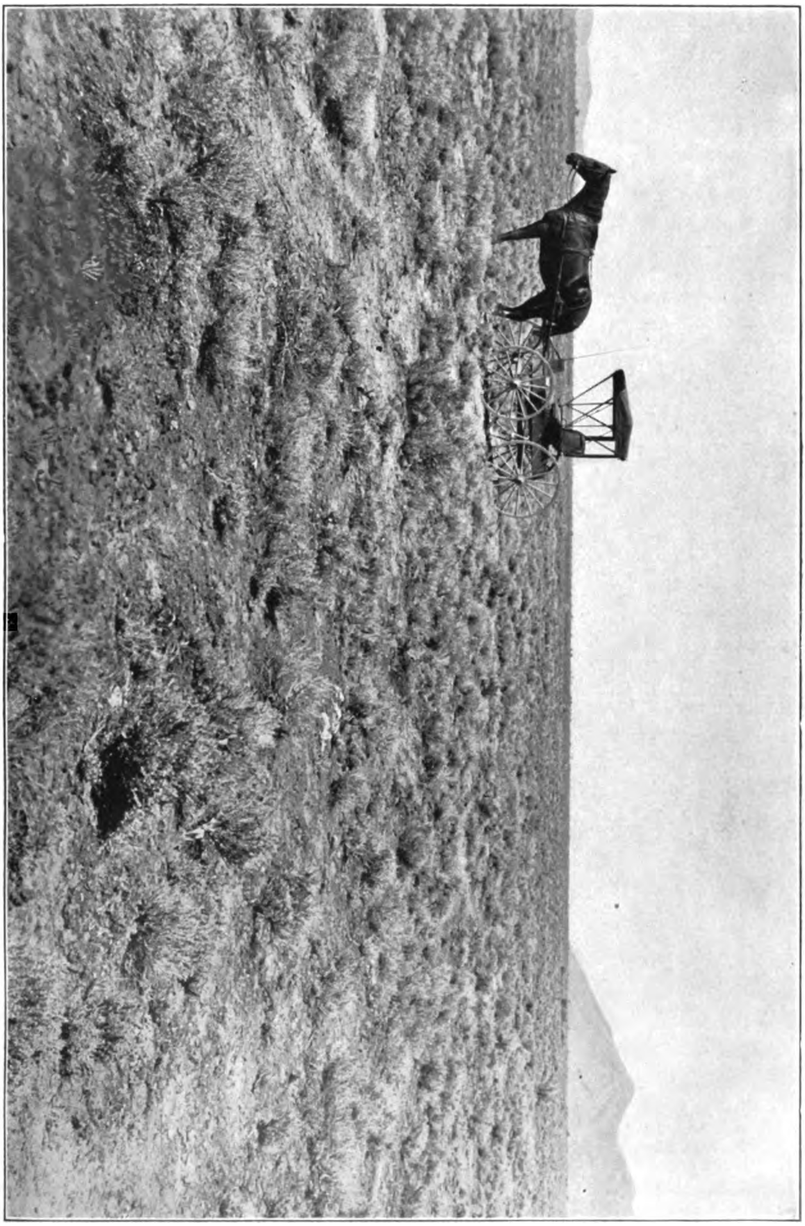
FIG. 21.—Profile of valley at Elsinore, Utah: *Rl*, Redfield loam; *Bgl*, Bingham gravelly loam; *Gl*, Glenwood loam; *Ssc & Gr*, Sandy loam and gravel.

the United States Weather Service. Since March, 1899, the precipitation has been unusually low. From that date to the close of 1900, a period of twenty-one months, it was only 4.64 inches.

The present soil survey was made during June, July, and August, 1900, by the Division of Soils, in cooperation with the Utah Agricultural Experiment Station.

All principal canals have been mapped and their waters examined with reference to their quality for irrigation purposes. Water was examined from the river, artesian wells, surface wells, and springs, and fully 60 analyses were made, the results of which are found in this report. Cross sections of the valley at Elsinore, Richfield, Salina, and Gunnison, showing the topography and soil section across the valley for these four places, are given in figs. 21 to 24.

In general the valley is level, there being a fall of about 7 feet per mile in the direction of the river and a fall from the base of the mountains to the river which usually does not exceed this, but at the mouth of inflowing streams the valley attains a maximum slope of about 100 feet per mile.



SEVIER VALLEY NEAR RICHFIELD, NATIVE VEGETATION SHAD SCALE.

The soils, usually light in texture, are formed largely from the adjacent mountains, although in certain level areas along the present river channel are deposits of material brought down from far up the valley. Owing to their mode of formation the soils are very diversified in character. At Joseph, Elsinore, and Monroe the soils are formed largely from igneous and lava rocks, and are consequently dark in color, while at Richfield the red sandstone gives rise to a soil of similar texture but almost vermilion in color.

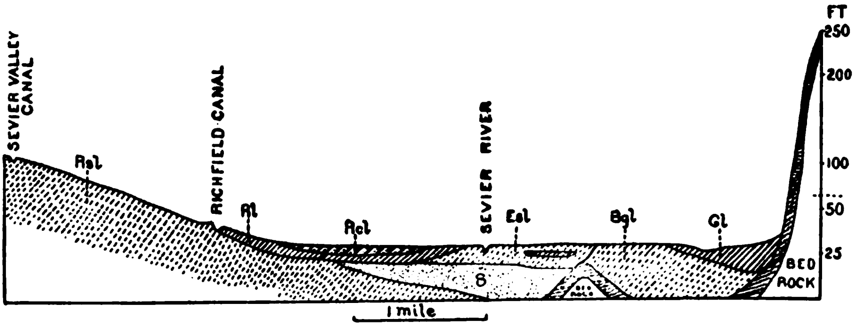


Fig. 22.—Profile of valley at Richfield, Utah: *Rsl*, **Redfield sandy loam;** *Rl*, **Redfield loam;** *Rcl*, **Redfield clay loam;** *Esl*, **Elsinore sandy loam;** *Bgl*, **Bingham gravelly loam without gravel at this place;** *Gl*, **Glenwood loam.**

About Joseph, Elsinore, and Monroe the soils are underlain by well-rounded, coarse river gravel, which continues for several hundred feet in depth, with occasional intervening strata of finer material or clay. In the river bed and over certain adjacent areas this gravel comes directly to the surface. It extends well toward the foothills, but is there covered by a much greater depth of soil. As we go northward

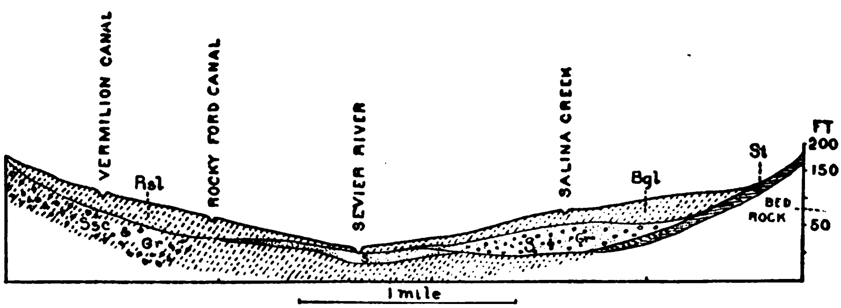


Fig. 23.—Profile of valley at Salina, Utah: *Rsl*, **Richfield sandy loam;** *Bgl*, **Bingham gravelly loam without gravel at this place;** *S*, **sand;** *S & Gr*, **sand and gravel;** *St*, **stone.**

along the valley this gravel becomes smaller and is found at a greater depth beneath the surface. At Elsinore the river bed takes water very rapidly, while east of Richfield seepage returns to the river in considerable quantity, and there is a large area of wet land in the vicinity. There are also large springs at the base of the mountains to the east, and it is not improbable that the source of much of this water is that which sinks in the river bed from Elsinore south.

The soils in the vicinity of Centerfield, like those at Elsinore, are underlain by river gravel to a great depth, the source of the material being from the San Pitch River.

The flora of the valley consists chiefly of greasewood, shad scale, rabbit bush, salt grass, foxtail, and a few other salt-loving species of annual plants. Sage bushes occur on the foothills and mountains, but are rarely found in the valley, owing to the usually salty condition of the virgin soils. The character of the vegetation bears an intimate relation to the kind of soil and to its condition, and a knowledge of this relation is of great assistance to the soil expert in mapping both soils and alkali.

Salt grass and foxtail indicate plenty of moisture at the surface of

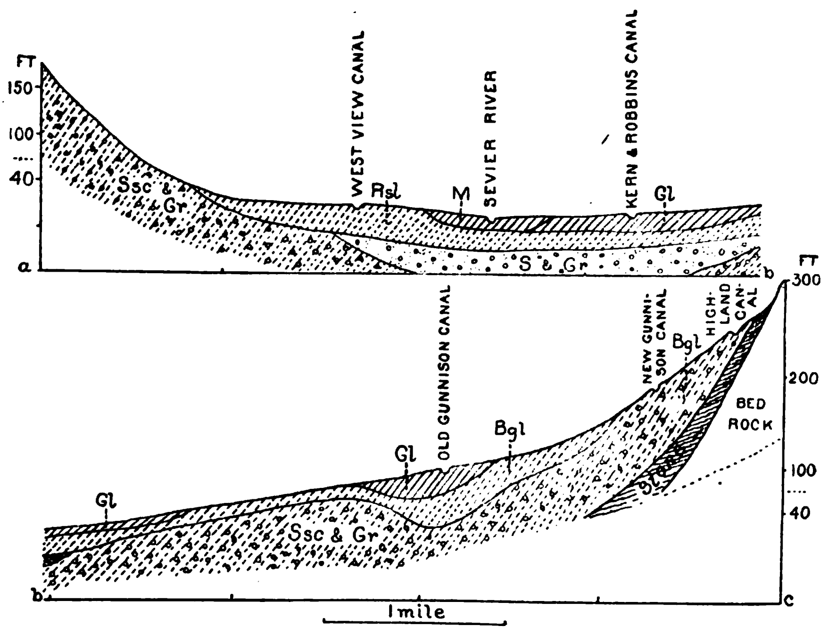


Fig. 24.—Profile of valley at Gunnison, Utah: *Ssc & Gr*, Mountain slope; *Rsl*, [illegible] sandy loam; *M*, Meadow; *Gl*, Glenwood loam; *Bgl*, Bingham gravelly loam.

the ground, and consequently the presence of free ground water not far below the surface; while the salt grass indicates the presence of considerable salt, especially at or near the ground surface. Either of these plants is found on any type of soil. Greasewood indicates dry land of medium texture, containing considerable salt.

A heavy growth of greasewood, to the exclusion of other plants, indicates 0.6 per cent or more of salt in the upper 5 feet of soil. If the growth of greasewood is less flourishing, partly giving way to shad scale, the salt content will most likely be from 0.4 to 0.6 per cent. Shad scale alone indicates dry land with less than 0.4 per cent of salt and oftentimes less than 0.2 per cent. Rabbit bush flourishes best on

very sandy soils that are comparatively free from salts, and it will be seldom found to any extent under any other conditions. Sweet clover and foxtail, in fields of alfalfa or grain which have a poor stand, indicate wet land and probably from 0.2 to 0.4 per cent of salts. Bare spots in fields of grain or alfalfa indicate alkali, usually 0.2 per cent or slightly more for the general average of the field, but much more than this on the spots.

As a rule, the virgin soils of the valley are salty, owing to the fact that the salts are formed faster by the rapid disintegration of rocks than they are carried away by the scanty rains. In the vicinity of Joseph, Elsinore, Monroe, and Central the underlying gravel affords such good natural drainage that when these lands are placed under irrigation the salts are soon carried deep into the soil, where they can do no harm to the plants, and from whence they eventually find their way to the river in the seepage waters. Where the drainage is poor it is difficult to bring these lands into a condition of profitable cultivation without resorting to underdrainage. Fortunately the larger part of the lands of the Sevier are naturally well underdrained. Between Richfield and Glenwood there is a considerable area that needs drainage before it can be profitably reclaimed and cultivated.

The salt map, as constructed, shows the alkali conditions at the time of its construction, June to August, 1900; but a few years hence the conditions may be considerably changed through bringing virgin lands under irrigation, and thus washing the salts out; in other places the salts may be actually increased through the accumulation of seepage waters.

HISTORY OF IRRIGATION.

The first settlers entered the Sevier Valley in the early sixties. They were at first very much annoyed by the Indians, and in some instances were driven from their homes by them. A few small canals were in use previous to 1870, but it was from 1870 to 1880 that most of the important canals were constructed. The South Bend and Sevier Valley canals, as well as several others, have been constructed since 1880.

The population is purely a pastoral one, there being no manufacturing in the valley. The people live in villages and farm the adjacent lands, often to a distance of 5 miles or more from the town. This mode of living has its advantages from a social standpoint, but is inconvenient and wasteful of time in carrying on the farm operations. The average farms are comparatively small, seldom being larger than 40 acres, although there are a few large ranches of several hundred acres each.

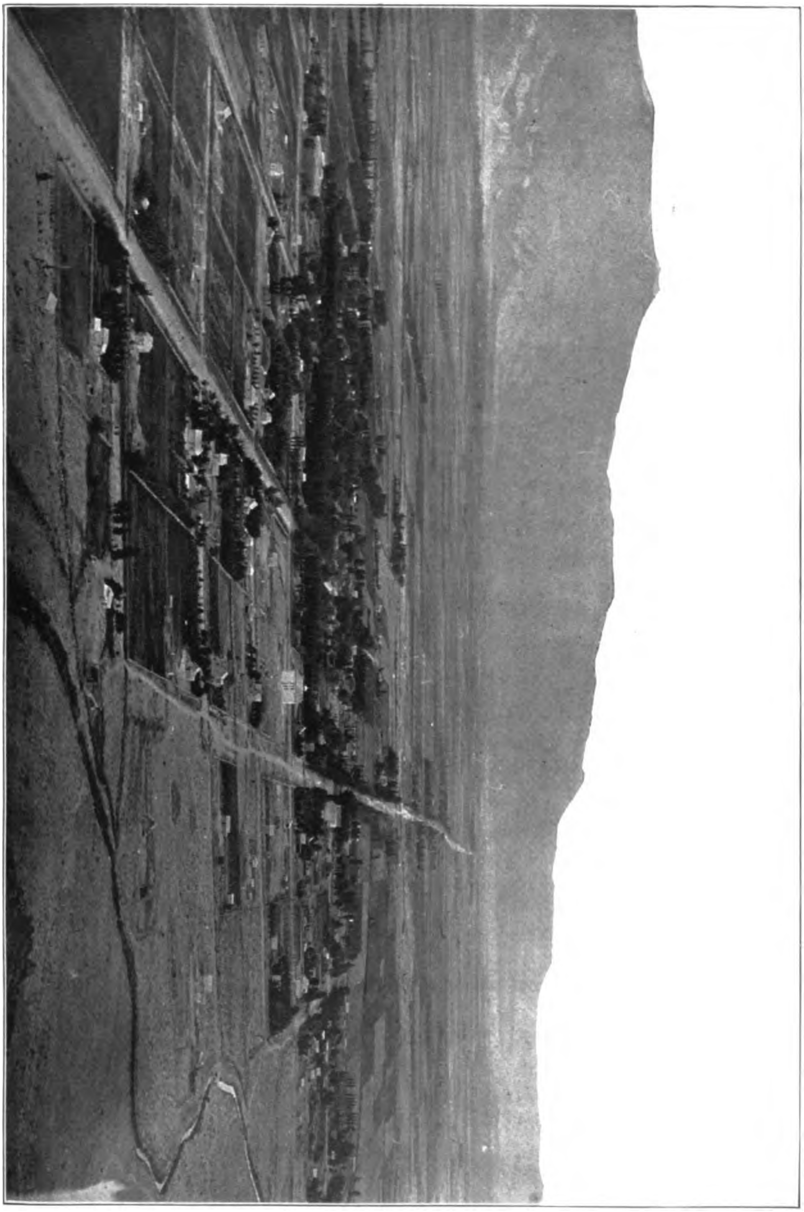
For the most part the valley is surrounded by a range country where thousands of sheep and a less number of cattle and horses find good pasture during the summers. As a consequence, the chief crops of the valley are alfalfa and grain used for feeding the stock brought into

the valley for the winter season. Alfalfa is first in importance both in acreage and in money value, while the cereals (oats, wheat, and barley) are the other chief crops. A few hundred acres of sugar beets were grown in 1900, and a movement is now in progress to establish a beet-sugar factory in the valley. As a rule, very little attention has been given to fruit raising, although a few small orchards are living examples of the good results that might be expected from this enterprise. At least enough fruit for home consumption should be grown. In the villages most of the houses have from 1 to 2½ acres of land, used for the production of all kinds of garden and vegetable products for home consumption. As a rule, the methods of farming are susceptible of great improvement. The farmers are lacking in enterprise, and should awaken to the fact that undeveloped opportunities lie close at hand. Better cultivation and larger yields should be sought.

At the south end of the valley the older canals are the Richfield, Elsinore, Brooklyn, Monroe, and Annabella. Two very important highland canals, the Sevier Valley on the west and the South Bend on the east, have more recently been constructed. Each canal is the joint property of the landowners and most of them were constructed by the cooperative labor of these owners. Each canal company elects officers, usually consisting of a president, secretary, board of directors, and water master, the last named being the only one paid for services rendered. It is the duty of the water master to see that the canal and its gates are kept in good repair and to apportion the water supply to the various shareholders. The annual assessment for repairs and maintenance rarely exceeds from 50 to 75 cents per share and is payable in work, material, or money.

Each canal receives from the river an amount of water proportional to its rights in the same. The proportioning of the water to the different canals is attended to by a river water master, who is elected and paid for services rendered by the various canal companies. When there is plenty of water each canal company gets all it wants, but when there is a shortage each company bears its proportional share of the same. The company water master adjusts the head gates of the various ditches taken from the canal so that each will receive water in proportion to the shares to which it supplies water.

A schedule is made out for the irrigation season for each ditch, showing the days and hours that each shareholder is entitled to use the water. A shortage of 25 per cent in the water supply for the canal means the same shortage for each ditch taken from it and does not change the schedule of the irrigation. Each share is supposed to irrigate 1 acre of land, but a man having 10 shares may use that amount of water on as much or as little land as he may choose. The furrow method of irrigation is used almost entirely, that is, small furrows, from 3 to 6 inches deep at intervals of from 2 to 2½ feet,



THE TOWN OF ELSINOR.

extend down the sloping direction of the field, and the irrigation stream is broken up and turned into these small furrows at a rate just sufficient to keep the water running to the lower end of the furrows and yet not to waste it by running beyond. The water from the Sevier River at times contains considerable sediment, so that most of the canals taken from it are lined with sufficient sediment to prevent much leakage, and there is very little trouble from this source. The Richfield Canal, however, leaks considerably in the vicinity of Richfield, and is partly responsible for the land along the railroad from 1 to 2 miles south of the town that is damaged by alkali and seepage.

The Vermilion Canal, supplied chiefly by seepage water, is quite level, and becomes so filled with moss that the movement of water in it is often very slow. By letting the water out of the canal for one or two days the bright sun would kill the moss, and when the water was again turned in the moss would cause no trouble. Another effective way of getting rid of the moss is to run a disk harrow through the canal. This agitates the mud, which becomes entangled with the moss, and upon settling carries the moss to the bottom, where it offers no obstruction to the flow of the water.

The Rocky Ford Canal has one of the most constant and surest water supplies in the valley, the source being chiefly from springs that occur about Glenwood and northward along the base of the mountains on the east side of the valley. The canal is nearly 15 miles long and irrigates a narrow strip extending parallel to the river, aggregating between 3,000 and 4,000 acres. The West View, Dover, and Kearns & Robbins canals all depend on seepage waters during the drier portion of the year. The water of these canals is very salty and does not give good results, as is shown by the condition of most of the farms under them. The canals about Gunnison and Centerfield get their supply as follows: For 5,000 acres, from the San Pitch River; for 6,000 acres, from Six, Nine, and Twelve Mile creeks. Besides these there are a number of streams entering from the east, which furnish water for limited areas. Monroe Creek, Salina Creek, Willow Creek, and large springs at Richfield and Glenwood are important sources of water for small areas, aggregating not less than 3,000 acres.

ORIGIN AND FORMATION OF THE SOILS.

The general evenness of the valley is one of the first points observed, there being comparatively little slope between the bottom of the valley and the base of the mountains, excepting at the mouths of the small canyons. Some of the mountains are quite high, Monroe Peak being 11,240 feet in elevation, and are quite precipitous and craggy.

The range of mountains on either side contributes the material for the soils on their respective sides of the valley. From the predomi-

nating red sandstone of the mountains on the west side originate the red-colored soils there, while the darker soils on the east side of the valley find their origin in the dark-colored igneous and lava rocks which there predominate.

The mountains are closely set with small hollows and ravines between the larger canyons, from which, by the aid of rains and snows, the weathered rocks have been transported to the valley. Each of these canyons has a small alluvial cone of its own, the apex of which is generally made up of large stones and bowlders and the interstices filled with finer material. Near the periphery the soil is finer, with little or no gravel. The influence of the Sevier River is shown, there being a narrow strip of sandy soil along its course caused by the deposition of rock material carried down by the water. This sandy soil is sometimes covered to the edge of the river by the mountain soil.

The mountains all about the country have been very thoroughly shaken up. The strata of sandstone have been left in all conceivable conditions—vertical, horizontal, in curves, and at any angle between vertical and horizontal. During the upheaval at the end of the Cretaceous period the mountains on the sides were raised, while a deep canyon was formed where the valley now is, down which the waters rushed, filling the canyon with gravel and sand. The first filling would, of course, go on so rapidly that the disintegrated material from the side mountains would have but little effect in the process. At a later period, when the water grew less in volume and as the mountains became more disintegrated, they were the chief source of the soils of the valley. Borings to a depth of several hundred feet show chiefly sand and gravel, with an occasional stratum of clay. This may indicate that the water from the canyon above and from the surrounding mountains took turns in forming the soil, the water from the canyon doing very little while the strata of clay were being formed from the adjacent hills. The character of the rocks in the mountains and the fossils which they contain give evidence that both the valley and mountains were once on the same level, and both were submerged, first by fresh water and then by salt water.

Between Elsinore and Joseph the bed of the river is gravel, and when a stream large enough for an ordinary canal is turned into the dry river bed the water gradually and entirely disappears by sinking into the gravel. Water thus sinking in this part of the valley is the probable source of the large springs and artesian wells which occur further down the river in the vicinity of Richfield and Glenwood.

The material from the adjacent mountains varies in depth from 100 feet or more near the mountains to a thin covering near the limit of transportation, where it often covers the river soil.

The red color of the soil on the west side of the valley is due chiefly to the abundance of ferric oxide in it. The soils in their virgin state contain all the essential elements for crop purposes—nitrogen from

organic material; potash from feldspar; phosphorus from phosphate rocks; calcium from calcite, dolomite and calcareous sandstone; iron from iron oxides; magnesium from dolomite; sulphur from gypsum, and probably from other sulphates; as well as chlorine, silicon, and aluminum.

SOILS.

The soils have been classified, according to their texture and formation, into ten types, which are shown in different colors on the map. The names, areas, and descriptions of the soils follow:

Areas of the different soils.

Soils.	Area.	Per cent of total area.	Soils.	Area.	Per cent of total area.
	Acres.			*Acres.*	
Redfield sandy loam	44,200	29.4	Meadow land	10,200	6.8
Bingham gravelly loam	38,400	25.6	Elsinore sandy loam	7,800	5.2
Bingham stony loam	16,600	11.0	Redfield clay loam	3,800	2.5
Redfield loam	14,100	9.4	Elsinore sand	1,900	1.3
Glenwood loam	12,100	8.0	River wash	1,300	.8

While the soils contain all the mineral elements of fertility, in their virgin state they produce only a scanty vegetation because of the insufficient rainfall.

REDFIELD SANDY LOAM.

Redfield sandy loam embraces a greater area than any other one type of soil in the valley, there being about 44,200 acres, or 29.4 per cent of the whole area surveyed. This loam is confined to the west side of the valley. Beginning just north of Elsinore, it extends northward along the entire remaining length of the Richfield district and throughout the length of the Gunnison district. The soil is formed from the mountains to the west, and like them it is for the most part quite red in color. Generally it slopes more rapidly toward the river than the soils on the east side of the valley.

This type of soil occurs in two phases: One portion, a sandy loam, continuing about the same in texture for an undetermined depth, but sometimes underlaid by gravel at 3 feet or more below the surface; the other, a soil in which more or less rounded, medium-sized gravel occurs within 3 feet or less of the surface, often coming directly to the surface. Irrigation is confined almost entirely to the first-named portion of this soil, the larger part of which occurs in the Richfield district. There are also some areas along the lines of the Vermilion and Richfield canals in the vicinity of Aurora in the Gunnison district. A profile of this portion of the Redfield sandy loam to a depth of 6 feet shows it to be uniformly a sandy loam.

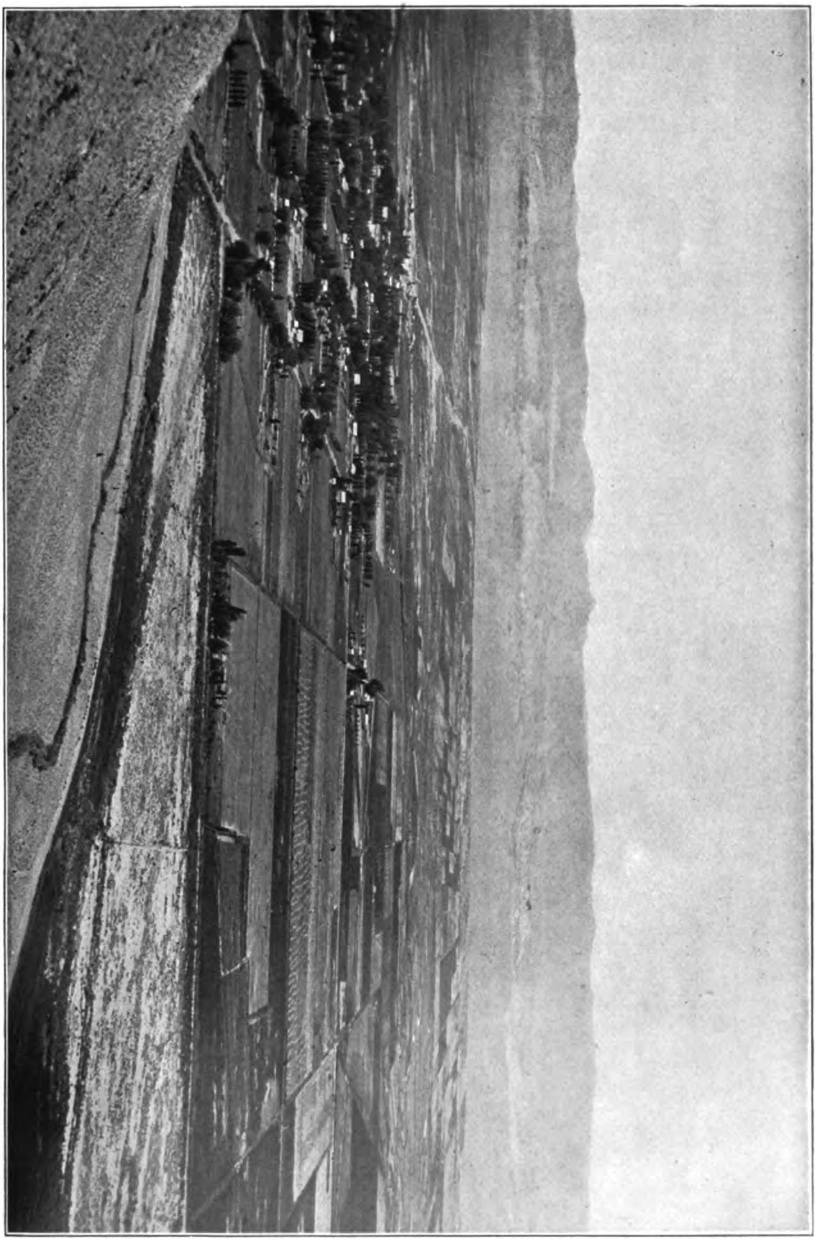
The following table of mechanical analyses shows the texture of the

soil to consist principally of the finer grades of sand and silt, with an average of about 12.4 per cent of clay. There is practically no difference in the texture of the different depths.

Mechanical analyses of Redfield sandy loam.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Soils, 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4950	Near West View	Gravelly bench land (28.5 per cent of gravel).	0.39	7.56	6.55	5.78	12.91	21.01	28.40	12.19	5.20
4894	C. of NE. ¼ sec. 26, T. 23 S., R. 3 W.	Dry virgin land	.43	7.43	Tr.	1.64	.48	9.98	43.39	28.17	7.76
4906	C. of SE. ¼ sec. 8, T. 23 S., R. 2 W.	do	.59	3.17	.87	2.81	3.39	17.34	27.47	32.42	11.67
4755	N. C. of sec. 22, T 24 S., R. 3 W.	Rough settled land.	.50	4.11	Tr.	1.67	2.54	12.26	39.98	26.54	11.50
4752	do	Unsettled land	.54	5.90	Tr.	3.32	3.13	15.88	32.57	26.54	12.05
4738	S. C. sec. 10, T. 24 S., R. 3 W.	Rough settled land.	.36	6.72	.54	1.39	2.18	10.28	16.99	43.08	17.64
4928	¼ mi. W. of C. sec. 27, T. 21 S., R. 1 W.	Alfalfa land	.52	3.25	0.00	0.00	Tr.	1.30	22.82	50.98	20.93
	Mean		.45	5.45	1.14	2.52	3.52	12.58	30.27	31.42	12.39
	Subsoils.										
4895	Sandy loam, 24 to 36 inches.	Under No. 4894	.43	7.78	Tr.	2.15	1.35	16.50	30.40	28.40	12.93
4896	Sandy loam, 48 to 60 inches.	do	.49	4.86	Tr.	.88	.82	9.46	21.02	44.42	18.14
4907	Sandy loam, 24 to 36 inches.	Under No. 4906	3.10	7.09	Tr.	2.54	2.54	10.12	22.06	45.34	6.30
4908	Sandy loam, 48 to 60 inches.	do	1.84	9.83	Tr.	1.45	2.34	12.15	27.20	36.34	8.18
4756	Sandy loam, 34 to 36 inches.	Under No. 4755	.48	2.64	1.69	6.05	7.10	22.04	30.43	20.70	8.07
4757	Sandy loam, 48 to 60 inches.	do	.54	5.93	2.26	5.53	5.78	17.55	27.02	26.06	10.05
4753	Sandy loam, 24 to 36 inches.	Under No. 4752	1.61	1.37	Tr.	2.26	3.95	22.58	38.00	20.63	8.50
4754	Sandy loam, 48 to 60 inches.	do	1.17	5.14	Tr.	1.16	2.53	16.24	40.07	25.93	7.46
4739	Sandy loam, 24 to 36 inches.	Under No. 4738	.43	6.57	Tr.	4.59	5.60	18.63	26.44	28.11	9.87
4740	Sandy loam, 48 to 60 inches.	do	.42	4.57	Tr.	4.80	5.37	24.64	32.36	18.69	7.76
4929	Sandy loam, 24 to 36 inches.	Under No. 4928	.53	7.06	0.00	.51	.42	2.66	19.23	48.66	19.25
4930	Sandy loam, 48 to 60 inches.	do	.56	8.28	0.00	Tr.	1.71	11.20	21.37	43.80	12.78

While this type of soil is usually free from injurious amounts of alkali, yet there are certain areas shown on the alkali map where the salt content is sometimes as great as 1 per cent. These salty areas are chiefly along the Richfield Canal, some distance northeast of Richfield, and along the Vermilion and Rockyford canals between Aurora and Redmond. The alkali areas are largely under the irrigation canals and are cultivated to a considerable extent. Owing to the scanty water supply it requires several years of irrigation to sufficiently reclaim the land, by leaching out the salts, for the profitable



TOWN OF SALINA WITH MAIN IRRIGATING CANAL IN THE FOREGROUND AND STRIP OF ALKALI LAND JUST BELOW, AND FERTILE FIELDS IN THE DISTANCE.

growth of crops. This type of soil, when free from injurious amounts of alkali, makes excellent land for alfalfa and grain. Between Elsinore and Richfield is a large area of this land which, upon the application of irrigation water, settled over a large part of its surface, the land thus being left in a very uneven condition. This settling was in places so great that the surface of the ground was sometimes lowered as much as 10 or 12 feet. This area lies directly below the mouth of Flat Canyon, and at some time not far remote a cloud-burst in the mountains evidently brought down large amounts of débris in the form of rocks, soil, and scrub cedars, which lodged there, after which disintegration continued, but without causing much settling of the material. When thoroughly wet the ground settles in a marked degree. A boring to a depth of 18 feet was made in an unsettled portion of this soil, and another boring, at a distance of 75 feet, was made where the soil had settled. The only difference apparent at the time was that the unsettled portion was loose and evidently contained cavities, while the settled portion was uniform throughout. The field determinations showed a considerably higher per cent of salts in the unsettled part.

In view of the frequent occurrence of gypsum in Flat Canyon, and of the statements made by certain farmers that a white material, which seemed to dissolve when irrigated, was frequently present in the lower depths of the soil, it was thought that deep borings might reveal that the settling was actually due to the occurrence of gypsum which dissolved upon the application of irrigation water and allowed the surface soil to settle. This material was not found in sufficient amount to make such a theory tenable, and the former explanation seems the more plausible.

The following table gives the composition of the water-soluble salts in the settled and unsettled portions of the soil at various depths:

Percentage composition of water-soluble salts.

Constituent.	Depth in virgin unsettled soil.							Depth in irrigated settled soil.						
	1 foot.	3 feet.	5 feet.	9 feet.	13 feet.	15 feet.	18 feet.	1 foot.	3 feet.	5 feet.	9 feet.	13 feet.	18 feet.
Ca	14	24	22	20	20	21	21	15	13	17	21	20	20
Mg	3	2	3	3	4	3	3	3	4	3	2	4	1
Na	7	2	2	3	3	1	3	5	6	3	4	2	1
K	3	1	2	3	1	6	2	4	4	2	3	3	4
SO_4	4	66	64	61	64	61	62	6	8	7	52	59	62
Cl	7	1	2	8	3	3	3	6	3	7	2	1	1
CO_3	2	1	1	0	0	0	0	1	3	0	0	0	0
HCO_3	60	3	4	7	5	5	6	60	59	62	17	11	8
Per cent soluble	0.67	1.57	0.85	0.75	1.13	0.97	0.92	0.25	0.19	0.20	0.40	0.53	0.82

The second, or gravelly, phase of this soil lies usually above the present canal systems, and occurs principally in the Gunnison dis-

trict. It has a considerable slope as far north as Redmond, north of which it takes the form of a bench, with a terrace along the eastern border. With the exception of a small and comparatively low portion near the junction of the San Pitch and Sevier rivers, this area is free from injurious amounts of salts. The vermilion color so pronounced about Richfield becomes more somber to the north, probably owing to the presence of less of the oxides of iron, which give rise to the color.

BINGHAM GRAVELLY LOAM.

This type of soil ranks second in extent and first in agricultural value. It includes 28,400 acres, or 25.6 per cent of the area surveyed. It is divided into two phases of about equal extent—one of a dark color, occurring in the Richfield district and also in the Gunnison district as far north as Lost Creek; the other of a light color, occurring in the last-mentioned district from Lost Creek northward. The first phase is the predominating type of soil in the southern part of the Richfield district, and occurs at intervals in small tracts along the east side of the valley as far north as Lost Creek, in the Gunnison district. It is usually of a dark color, in contradistinction to the light-colored Elsinore sandy loam and the red-colored Redfield sandy loam which occurs on the west side of the valley. The dark color is due chiefly to its origin—the lava rocks from the adjacent mountains.

In the vicinity of Joseph and Monroe this type of soil is quite generally gravelly, the gravel being, as a rule, small and more or less rounded, so that it does not interfere with cultivation, even when it occurs immediately at the surface, which it often does. The gravelly areas on the map show gravel within 3 feet or less of the surface. All of this type of soil occurring south of Annabella is underlaid with gravel at a depth rarely greater than 10 feet. In the vicinity of Glenwood the gravel is less abundant. A profile of the soil to a depth of 6 feet shows, on an average, continuous sandy loam with gravel below 2 feet. It must of course be recognized that gravel sometimes occurs throughout the profile, while in other cases it is entirely absent.

A large percentage of this land is under cultivation, and gives excellent results with both alfalfa and grain. In its lighter and more gravelly portions it is well adapted to fruits. Three miles southwest of Monroe is a nursery and fruit farm, on which apples, pears, peaches, and various kinds of small fruits are doing well. The land is easy of cultivation and retains moisture remarkably well.

The following table shows the texture of this phase of the soil, as

determined by the mechanical analyses of samples from different parts of the area:

Mechanical analyses of Bingham gravelly loam, dark-colored phase.

No.	Locality.	Description.	Salts as determined in mechanical analysis	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Soils 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4731	One-fourth mile N. of SE. C. sec. 14, T. 25 S., R. 4 W.	Cultivated land (gravel 27.5 per cent).	0.26	2.72	0.00	1.69	3.49	28.11	41.36	16.06	6.61
4735	SE. C. sec. 17, T. 25 S., R. 3 W.	....	.47	1.88	15.16	13.36	9.22	22.40	17.18	14.10	7.07
4733	C. of sec. 28, T. 25 S., R. 3 W.	Cultivated land (gravel 11.8 per cent).	.27	2.19	12.48	14.54	9.60	25.84	18.03	9.39	7.35
4744	C. of NE. ¼ sec. 5, T. 25 S., R. 3 W.	Cultivated land (gravel 8 per cent).	.43	4.52	2.03	2.58	4.72	28.09	22.11	23.65	12.70
4726	One-fourth mile N. of C. sec. 14, T. 25 S., R. 4 W.	Good alfalfa land.	.35	5.33	0.00	1.76	1.62	7.94	34.38	35.36	13.69
	Mean.........	....	.36	3.33	5.93	6.79	5.73	22.48	26.61	19.70	9.58
	Subsoils.										
4732	Sandy loam, 24 to 40 inches.	Under No. 4731...	.26	3.35	0.00	Tr.	1.29	12.76	43.20	33.01	5.62
4734	Sandy loam, 12 to 36 inches.	Gravel 10.3 per cent under No. 4733.	.35	3.75	3.02	3.01	2.80	9.50	17.28	38.10	22.11
4745	Sandy loam, 24 to 30 inches.	Gravel 30 per cent under No. 4744.	.51	3.46	3.68	6.60	5.83	26.60	27.26	20.74	5.00
4727	Sandy loam, 18 to 36 inches.	Under No. 4726...	.31	2.62	5.65	14.05	10.28	25.49	19.87	13.09	8.35

A glance at the salt map shows that, with the exception of a small area in sec. 1, T. 25 S., R. 4 W., and a strip west of Glenwood along the west side of Cove Creek, this type of soil as it occurs in the Richfield district is quite free from injurious amounts of salts. In the Gunnison district, however, a considerable amount of it is salty, especially near Lost Creek. In the salty areas the soil is usually virgin, and when brought under irrigation can be quite readily reclaimed, the salt being carried down into the usually porous subsoil.

The physical characteristics of the second phase of this soil are much like the former in regard to texture, gravel content, and mode of formation; but the color of the soil, the material from which it was formed, and the character of its salt content are very different. It is situated almost entirely in the Gunnison district and its water supply is derived chiefly from the San Pitch River and tributaries, together with small amounts from Saline and Willow creeks.

The origin of the soil is from the San Pitch Valley or from the mountains on the east. The soil is usually of a light-brown color

and, as will be seen by the map, contains gravel within 3 feet or less of the surface over most of its extent. In the vicinity of Centerfield the gravel is quite large and very well rounded. It was deposited there by the San Pitch River and continues to 100 feet in depth and perhaps several hundred feet deeper.

As a rule, even in the virgin state the higher parts of this area contain very little salt. This is largely due to its good slope and gravelly underlying stratum. In its lower depths, however, there is considerable salt, as shown by the character of the surface well waters. The lower and more level parts of the area are more or less salty in their virgin state, but are readily reclaimed upon the application of irrigation water. A glance at the alkali map will show that in secs. 12–20 and 30, T. 20 S., R. 1 E., there is considerable salty land, and also in sections 2 and 3 there are small areas having from 2 to 4 per cent; this salt, however, will readily disappear under judicious irrigation. A little more than one-third of this phase is now under irrigation, and the Highland Canal, which is now constructed to a short distance below Willow Creek, will bring a large additional area under the plow. This latter portion is usually light in texture, gravelly, and well adapted to the production of sugar beets, vegetables, and fruits. The lower part of this area is better suited to the production of alfalfa and cereals.

The following table of mechanical analyses gives an idea of the texture of this phase of the Bingham gravelly loam:

Mechanical analyses of Bingham gravelly loam, light-colored phase.

No.	Locality.	Description.	Salts as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Clay, 0.005 to 0.0001 mm.
	Soils 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*
4938	SE. ¼ of sec. 16, T. 20 S., R. 1 E.	Gravelly virgin land, gravel 10 per cent.	0.47	4.44	1.78	2.64	4.88	15.18	39.57	22.01	6.93
4945	NW. ¼ of sec. 28, T. 19 S., R. 1 E.	Cultivated gravelly land, gravel 21 per cent.	.50	9.00	6.02	5.08	3.98	11.52	20.08	32.80	12.47
4946	C. of sec. 23, T. 19 S., R. 1 E.	Virgin soil.......	1.80	7.77	Tr.	1.06	1.28	9.67	32.39	27.84	18.55
4939	W. C. of sec. 2, T. 20 S., R. 1 E.	.....do............	.32	6.53	Tr.	.68	.79	5.05	21.56	41.12	25.47
	Mean....	....	.77	6.93	1.95	2.37	2.73	10.36	28.40	30.94	15.85
	Subsoils.										
4947	Sandy loam, 24 to 36 inches.	Under No. 4946...	1.93	8.81	1.14	.91	1.38	4.52	29.45	38.59	13.29
4948	Sandy loam, 48 to 60 inches.	.....do............	1.31	8.81	5.67	5.93	4.10	7.62	23.42	27.23	16.93
4940	Sandy loam, 24 to 36 inches.	Under No. 4939...	1.97	3.81	.70	2.38	2.52	14.65	35.52	24.19	14.24
4941	Sandy loam, 48 to 60 inches.	.....do............	3.61	5.08	1.92	2.31	4.60	12.81	33.10	23.94	10.17

Sample 4939 shows too much clay in the top foot for a sandy loam; this, however, is only of local occurrence and is caused by a recent covering of fine material which has been brought down from the canyon just to the east and lodged in a flat area at this point. Just here is also a salty area, as will be seen from the alkali map. The third and fifth foot beneath, samples 4940 and 4941, are very much lighter in texture and are quite representative of sandy loam. Sample 4946 is also somewhat heavy for a sandy loam, but the soil becomes lighter below. These samples are from portions of this type of soil where the gravel is 5 feet or more from the surface and represent the heavier part of the soil. Samples 4938 and 4945 are from parts where the gravel is 3 feet or less from the surface and where the soil is much lighter in texture.

A profile representing the average character of this type of soil to the depth of 6 feet would be 3 feet of sandy loam, then 3 feet of sandy loam with gravel, continuing to an undetermined depth.

BINGHAM STONY LOAM.

The Bingham stony loam is located along the base of the mountains and occurs chiefly in the Richfield district. The material is derived mostly from the adjacent mountains, although at the mouth of canyons it is sometimes brought down from the interior of the mountain ranges. This land consists of a mixture of loam, sand, and gravel, in which is embedded loose rock coming directly to the surface or sometimes projecting above it. Near the base of the mountains it is usually underlaid with the bed rock of the mountains themselves, while farther out into the valley the same material often continues to a considerable depth. This land is of very little agricultural value—first, because,it is usually too stony to be successfully cultivated, and second, because it is usually situated above the highest irrigation canals, and therefore can not be watered. It is so dry and the vegetation is therefore so scanty that the value of the land for grazing is small.

In several localities there are small streams issuing from the adjacent mountains that could be used for irrigating some of this class of land, but where the water can be used on better lands lower down it is advisable to use it there. South of Monroe there are nearly a thousand acres of this land under the ditches taken from the Monroe Canyon, a portion of which could be successfully used for orchards, especially for the stone fruits, such as peaches, plums, etc. As shown by the alkali map, the Bingham stony loam is usually free from injurious amounts of alkali.

REDFIELD LOAM.

This loam originates from the red sandstone mountains to the west, as does the Redfield sandy loam which lies just above it. It occurs from Elsinore northward to the town of Vermilion, in the Richfield

district, and also in the Gunnison district for the greater part of its length. It covers an area of about 14,100 acres, or 9.4 per cent of the area surveyed. It lies below irrigation canals and is capable of cultivation; in fact a large percentage of it is being successfully cultivated. In the vicinity of Richfield and northward a considerable portion of this land is somewhat wet, the ground water standing within 3 feet or less of the surface. In these areas underdrainage would be of material assistance in improving the condition.

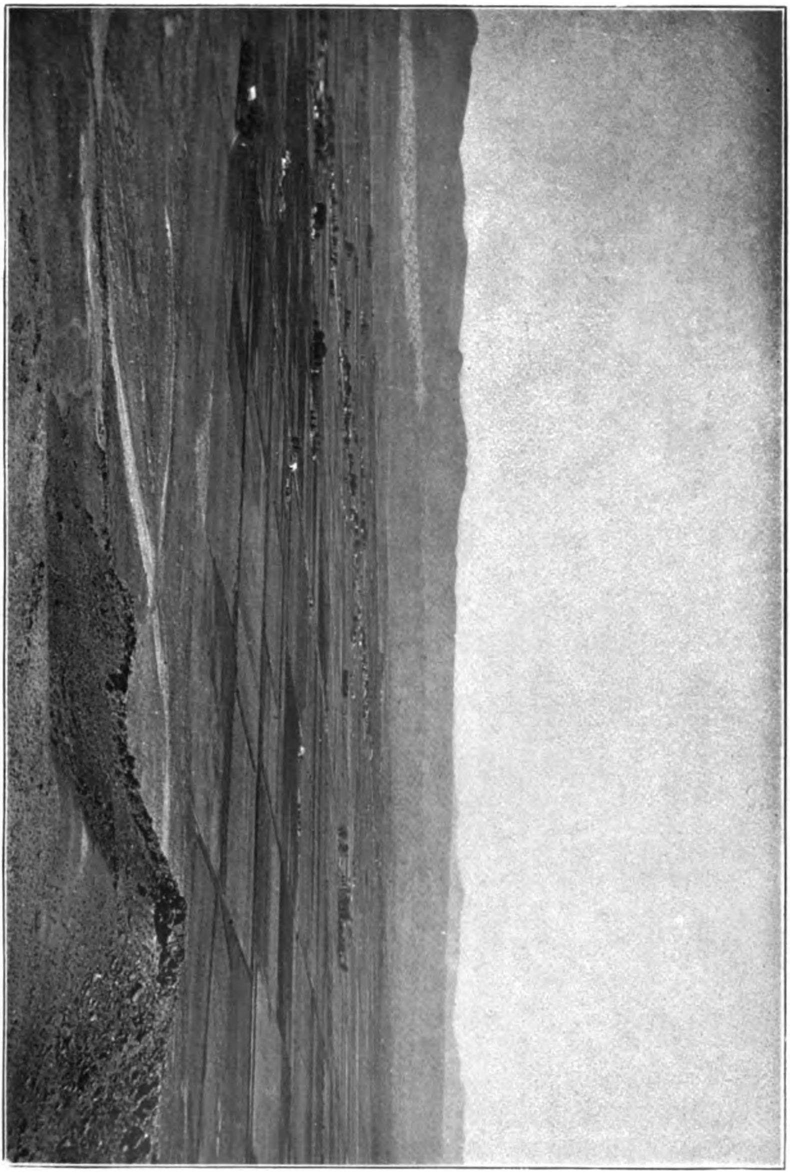
The alkali map shows that very little of this type of soil between Elsinore and Richfield is seriously troubled with alkali; northward from Richfield, however, much of it is quite salty, and generally in its virgin state it is covered with a good growth of greasewood and contains from 0.6 to 1 per cent of alkali. Both the Vermilion and Rockyford canals irrigate considerable portions of this land, and the alkali map shows many square or rectangular areas that differ in salt content from the adjacent land. This is due to the practice of irrigation, which is reclaiming this land in tracts of from 20 to 40 acres.

A profile of this soil shows an average of 4½ feet of loam underlaid by clay loam. In some instances the loam is continuous to great depths, while in others it is underlaid by sandy loam or sand. The latter condition is found where the loam borders on a soil of lighter type, which in some cases it overlaps, although it is more frequently overlapped by the lighter soil. This soil, especially when wet, is of a striking vermilion color.

The following table shows the texture of a number of samples which were taken from these areas. The heavy texture is not all accounted for by the clay content; but it will be noticed that the silt content is very high, averaging about 50 per cent of the total separations.

Mechanical analyses of Redfield loam.

No.	Locality.	Description.	Salts as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Soils 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4910	W. C. sec. 10, T. 23 S., R. 2 W.	Alfalfa land	1.49	6.61	0.00	Tr.	Tr.	0.85	5.75	55.99	28.64
4925	¼ mile N. of C. sec. 28, T. 24 S., R. 3 W.	.....do	.52	4.10	0.00	0.46	0.64	5.90	25.46	48.14	14.82
	Subsoils.										
4911	Loam, 24 to 36 inches	Under No. 4910.	1.15	9.54	0.00	0.00	Tr.	1.74	5.93	55.04	26.81
4912	Loam, 48 to 60 inches	.....do	1.41	12.16	0.00	0.00	Tr.	.94	5.88	51.73	29.29
4926	Loam, 24 to 36 inches	Under No. 4925.	.35	2.40	0.00	.76	.80	6.42	25.26	43.68	14.61
4927	Loam, 48 to 60 inches	.....do	.45	6.84	Tr.	1.26	2.46	14.51	22.01	41.28	11.76



VIEW UP THE VALLEY FROM THE HEIGHTS WEST OF GUNNISON.

GLENWOOD LOAM.

This type of soil, embracing 12,000 acres, or 8 per cent of the area surveyed, is of the same origin as the Bingham gravelly loam, being the finer material from the latter, which has been laid down at a greater distance from its source. Like the Bingham gravelly loam, it is also divided into two phases of corresponding origin. The first phase is the dark-colored soil which occurs in the Richfield district.

A profile of this portion shows about 4 feet of loam underlaid by clay loam. As a result of this heavy substratum, the work of reclaiming the virgin land when salty is rather slow, but when reclaimed it produces excellent yields of alfalfa and grain.

A comparison of the soil and alkali maps shows that from north of Monroe to Annabella this type of soil is quite free from injurious amounts of salts. That portion in the vicinity of Glenwood and northward, however, is not only salty but is very wet, and needs drainage before it can be successfully cultivated. That portion near Lost Creek is mostly under cultivation, but part of it has sufficient salt—from 0.20 to 0.40 per cent—to prevent uniform stands of crops grown. The trouble here is partly caused by the salty water from Lost Creek, which is used for irrigation.

The second phase of this type occurs in the Gunnison district. Its origin is from the same source as the second phase of the Bingham gravelly loam, being the finer materials from this loam which in the process of formation have been carried farther down before lodging. In the vicinity of Centerfield there is a small area where gravel occurs within 3 feet or less of the surface. Beyond this locality the gravel seems to have been suddenly covered, and while it may continue to the river it is either at that point at a very great depth or, possibly, entirely absent.

The following analyses show the texture of samples for the first and third foot, these samples being fairly representative of the texture of the gravelly portion of this type of soil. In the vicinity of Centerfield this land is all under cultivation and produces excellent yields of alfalfa and grain. A comparison of the soil and alkali maps shows that a considerable portion of this soil, where it borders on the meadow lands, is salty. It is not so readily reclaimed as the lighter soils, being heavy of texture, but it wears better, and for grain and alfalfa it is more productive than the lighter soils.

Mechanical analyses of Glenwood loam.

No.	Locality.	Description.	Salts as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Surface soil, 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4749	¼ mile W. of S. C. sec. 3, T. 25 S., R. 3 W.	Grain and alfalfa land.	0.46	5.16	1.56	1.76	1.72	7.59	13.25	46.10	23.80
4943	C. of sec. 30, T. 19 S., R. 1 E.	Cultivated land.	.82	10.05	0.06	Tr.	.52	2.52	9.29	45.13	31.41
	Subsoils.										
4750	Loam, 24 to 36 inches.	Under No. 4749.	.86	4.61	1.88	2.68	1.52	6.88	15.56	44.22	22.87
4751	Loam, 48 to 60 inches.	.....do..........	.60	3.42	2.80	3.82	2.45	10.44	17.90	39.15	20.38
4944	Loam, 24 to 36 inches.	Under No. 4943.	.66	8.32	0.00	0.00	Tr.	2.56	8.85	50.06	30.74

MEADOW.

The meadow land is an alluvial soil lying along the borders of the river, to which it chiefly owes its origin. It begins in the northeast corner of the Richfield district and widens to the north, extending the entire length of the Gunnison district. Its total area is 10,200 acres, or about 6.8 per cent of the entire area surveyed. In the vicinity of Redmond and for 3 or 4 miles northward there is considerable of this land cultivated; with this exception it is mostly in the virgin state, and is covered principally with salt grass and willows, the latter growing only where the salt content is less than 0.4 per cent. In texture it varies from a very light sandy loam to clay loam, but is usually a sandy loam, becoming slightly lighter in texture as the depth increases. It contains much organic matter in the upper portion, and consequently is of a black color. It is invariably salty, as shown by the alkali map, and becomes more so toward the north. As a rule, standing water is found to be 6 feet or less below the surface, although in T. 19 S., R. 1 W., there is considerable land where the water is not more than 3 feet from the surface. When the Sevier River rises, this land is no doubt somewhat wet.

With a good water supply and underdrainage it could be made into profitable farming land. There are a few good fields of grain and alfalfa near where Willow Creek enters the Sevier River that indicate the possibilities of this type of soil. The alkali is of the white kind and consists largely of chlorides, which have apparently come down from the salt hills and salty lands about Salina and have been left in the meadow lands by the seepage that there evaporates.

The following table shows the texture of this type of soil south of Redmond, which is probably somewhat lighter than the average:

Mechanical analyses of meadow land.

No.	Locality.	Description.	Salts as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4934	N. C. of sec. 23, T. 21 S., R. 1 W.	Virgin salt grass land, 0 to 12 inches.	1.92	8.11	0.00	0.00	1.11	14.95	30.21	30.37	9.10
4935	Sandy loam, 24 to 36 inches.	Under 4934	.95	3.30	0.00	0.00	1.28	36.44	41.88	7.40	7.83
4936	Sandy loam and sand, 48 to 60 inches.	......do	.91	3.33	0.00	Tr.	2.10	36.46	45.07	7.83	4.90

ELSINORE SANDY LOAM.

This type of soil is confined to the Richfield district. It comprises about 7,800 acres, or 5.2 per cent of the whole area surveyed, extending along the river in the eastern part of the valley from a point east of Elsinore northward to the vicinity of Vermilion.

The origin of this type of soil is far up the valley, the material having been brought down by the Sevier River. The coarse sand and gravel were left between Joseph and Monroe and the finer material brought down to form this area. The surface of this soil is a light-colored sandy loam, varying in clay content from 5 to 15 per cent, as shown in the following table of mechanical analyses. The underlying stratum, however, becomes more sandy as the depth increases, and at 6 feet it usually grades into gravel. The character of the underlying stratum is clearly shown for the depths of 3 and 5 feet in the analyses.

Mechanical analyses of Elsinore sandy loam.

No.	Locality.	Description.	Salts as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Surface soil, 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4900	One fourth mile N. of E. C. sec. 31, T. 23 S., R. 2 W.	Salt grass land.	3.35	6.17	0.00	2.33	3.97	19.92	32.80	26.95	5.19
4903	One-fourth mile S. of C. sec. 33, T. 23 S., R. 2 W.	Low wet land	.86	7.90	.00	1.22	1.91	9.91	24.06	46.27	8.01
4914	SW. ¼ of sec. 22, T. 23 S., R. 2 W.	Salt grass land.	1.05	3.74	Tr.	1.38	3.24	28.24	31.48	19.06	12.17
4741	One-fourth mile W. of C. sec. 13, T. 24 S., R. 3 W.	Low wet land	1.12	5.72	.00	Tr.	.44	2.54	32.60	44.92	12.31
4897	One-fourth mile S. of C. sec. 6, T. 24 S., R. 2 W.	Low level land.	4.10	8.22	Tr.	.58	.63	11.58	21.60	37.63	15.21
	Mean		2.10	6.35	.00	1.10	2.04	14.44	28.51	34.97	10.58
	Subsoils, 24 to 36 inches in depth.										
4901	Coarse sand	Under No. 4900.	.75	2.17	8.70	13.87	10.69	34.64	15.54	10.84	2.51
4904	Sandy loam	Under No. 4903.	.58	4.14	.00	Tr.	.42	2.39	30.59	53.98	7.98
4915	do	Under No. 4914.	1.08	3.38	.00	Tr.	.32	35.86	37.71	16.02	6.44
4742	do	Under No. 4741, gravel 8 per cent.	.75	3.23	Tr.	1.80	1.69	29.43	40.00	17.80	5.91
4898	do	Under No. 4897.	1.92	5.78	2.87	4.36	2.37	21.35	33.35	21.94	6.20
	Mean		1.02	3.74	2.31	4.01	3.10	24.73	31.44	24.12	5.81
	Subsoils, 48 to 60 inches in depth.										
4902	Sand and gravel	Under No. 4900.	.55	1.15	21.50	27.00	18.34	24.08	5.03	.69	.76
4905	Sandy loam	Under No. 4903.	.57	6.25	.00	Tr.	.20	2.69	36.40	47.35	8.22
4916	Loam	Under No. 4914.	1.00	5.05	.00	Tr.	.80	22.21	33.41	28.20	10.63
4743	Coarse sand	Under No. 4741, gravel 9 per cent.	.46	1.76	7.00	15.88	14.34	33.07	19.60	4.34	3.18
4899	Sand	Under No. 4897.	.67	2.84	5.46	9.64	8.35	40.90	16.23	11.88	3.16
	Mean		.65	3.41	6.79	10.50	8.41	24.59	22.13	18.49	5.19

Notwithstanding the very pervious character of the underlying stratum of this soil, under much of it water is found standing within 6 feet or less of the surface, and in secs. 28, 32, and 33, T. 23 S., and sec. 5, T. 24 S., there is a large area where the water is 3 feet or less from the surface. This wet condition has been ascribed to two sources, the chief of which is the large number of springs that occur all along the base of the mountains from Annabella northward to the point of the mountain west of the town of Glenwood. These springs not only keep the soil wet but send seepage to the river, which is later taken out and used for irrigation. On the west side of the river this soil is

somewhat affected by seepage from the canals and irrigated lands along the west side of the valley, especially from the district between Elsinore and Richfield.

A glance at the alkali map shows that most of this type of soil is more or less salty, the larger percentage of it having from 0.2 to 0.4 per cent of salts, with small areas having as much as 1 per cent. The larger part of the salts occur in the surface foot, salt crust being present at the surface in many places. The alkali is chiefly of the white kind, the black alkali being found only in small amounts. The source of these salts is largely the accumulating water, which evaporates from the wet soil and leaves its salts at or near the ground surface.

In its present condition this type of soil is of very little value, and indeed less than 1 per cent of it is farmed. Most of it produces a considerable growth of salt grass, which is used for pasturage or for hay. With very little drainage and with the application of irrigation water this land could be quickly and easily reclaimed and would make fair farms, especially for sugar beets and vegetables.

A drainage canal to collect the waters of the springs along the base of the mountains and conduct them into Cove Creek would be the first necessary step in the process of reclaiming the land. In this event the water for irrigating the land would probably have to come through an extension of the Annabella, Monroe, or South Bend canals.

REDFIELD CLAY LOAM.

This heavy type of soil occurs principally in the Richfield district and in the vicinity of the town of Redfield. While in places the clay loam continues to a considerable depth, yet it is more frequently underlaid by sand at a depth of 5 feet. Owing to its heavy character it contains much salt, which is difficult to remove. In the vicinity of Richfield it has become sufficiently free from salts to produce grasses. Even where salty, a good crop of salt grass used for pasturage is grown. Generally, this type of soil is wet, the water standing within 6 feet or less of the surface.

The following table shows the texture of the soil as determined by the mechanical analyses:

Mechanical analyses of Redfield clay loam.

No.	Locality.	Description.	Salts as determined in mechanical analysis.	Loss in ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Surface soil, 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4728	C. of sec. 23, T. 24 S., R. 3 W.	Level irrigated land.	0.83	9.19	0.00	Tr.	0.56	3.10	12.77	53.79	18.39
4891	C. of SE. ¼ sec. 2, T. 24 S., R. 3 W.	Wet salt grass land.	2.25	6.21	.66	0.92	.48	1.44	2.20	51.78	34.59
	Subsoils.										
4729	Clay loam, 24 to 36 inches.	Under No. 4728	1.87	7.09	.00	.00	Tr.	1.76	12.51	51.02	25.60
4730	Clay loam, 48 to 60 inches.	do	1.80	8.86	.00	Tr.	.61	1.67	7.76	54.98	24.48
4892	Clay loam, 24 to 36 inches.	Under No. 4891	1.44	5.71	.00	Tr.	.38	1.75	4.06	48.60	38.06
4893	Clay loam, 48 to 60 inches.	do	1.58	9.74	.00	.00	Tr.	1.86	4.09	50.69	31.46

ELSINORE SAND.

Another unimportant type of soil is the Elsinore sand, located along the river bank in the southern half of the Richfield district only. It constitutes about 1,900 acres, or only 1.3 per cent of the entire area surveyed. It is a coarse river sand, sometimes containing river-washed gravel, and always underlain by gravel. It is too leachy in character to be of much value for agricultural purposes.

RIVER WASH.

This soil, as the name implies, is practically nothing but a large amount of coarse river-washed gravel, with only a small percentage of fine material intermixed. In places there is sufficient fine material to make cultivated areas, but, as a rule, it is practically valueless for agricultural purposes. It occurs only in the Gunnison district and along the San Pitch River bed.

WATER SUPPLY.

The irrigation water supply for the Sevier Valley is, under its present management, inadequate to irrigate all of the land included in the present survey. By impounding all of the water from the close of the irrigation season to the opening of the same the next year, there would unquestionably be sufficient water to irrigate all of the land,

and in years of the greatest precipitation leave some to spare. Such an impounding of the water has already been commenced on Otter Creek, an important tributary of the Sevier. A reservoir is there formed by building a large dam across the creek near where it enters the Sevier River. The dam, now nearly completed, is of earth and stone, with a clay "core," which is well pounded. At its base the dam is about 200 feet wide, and the sides have a slope of 2½ to 1, making the height of the dam 40 feet. Crosswise of the stream the dam at its base is 150 feet long; at an elevation of 35 feet, 900 feet long, and at 40 feet in height, about 1,200 feet long.

When filled to the top of the dam the water of the reservoir extends up the Grass Valley a distance of 6 or 7 miles, with an average width of three-fourths of a mile, giving a capacity of slightly more than 41,000 acre-feet. The cost of the reservoir thus formed will be about $40,000.

It is now thought that the height of the dam can be increased to 45 feet, at which height the capacity of the reservoir will be about 60,000 acre-feet. This reservoir is designed to collect all of the waters from the Grass Valley, and, by means of a feeder canal, water is also conducted to it from the south fork of the Sevier River.

The water from the Grass Valley flows down through the meadows and is free from silt, so there will be no danger of the reservoir filling with this material. The construction of this important work materially increases the available water supply for irrigation and marks an important improvement.

During the winter and spring of 1899–1900 the precipitation of both rain and snow was unusually small, and the dam, although incomplete, was sufficient in height to retain all of the water from Grass Valley. The gates of the reservoir were opened June 1 and the water allowed to escape at the rate of 160 cubic feet per second. The flow continued at this rate until July 15, when the water was nearly exhausted. At the latter date the flow of the Sevier River, exclusive of the reservoir supply, was only about 30 second-feet. The water from the reservoir flows about 45 miles in the river bed before the first important canal takes it.

All of the principal canals in the upper part of the district have an interest in the reservoir and receive water from it, according to their proportional part of the entire capital stock. The following table gives the valuation of the capital stock for each canal; the percentage of same to the total; also the percentage of the normal river flow to

which each is entitled when said flow below Joseph is less than 101 second-feet:

Distribution of stock in Otter Creek reservoir.

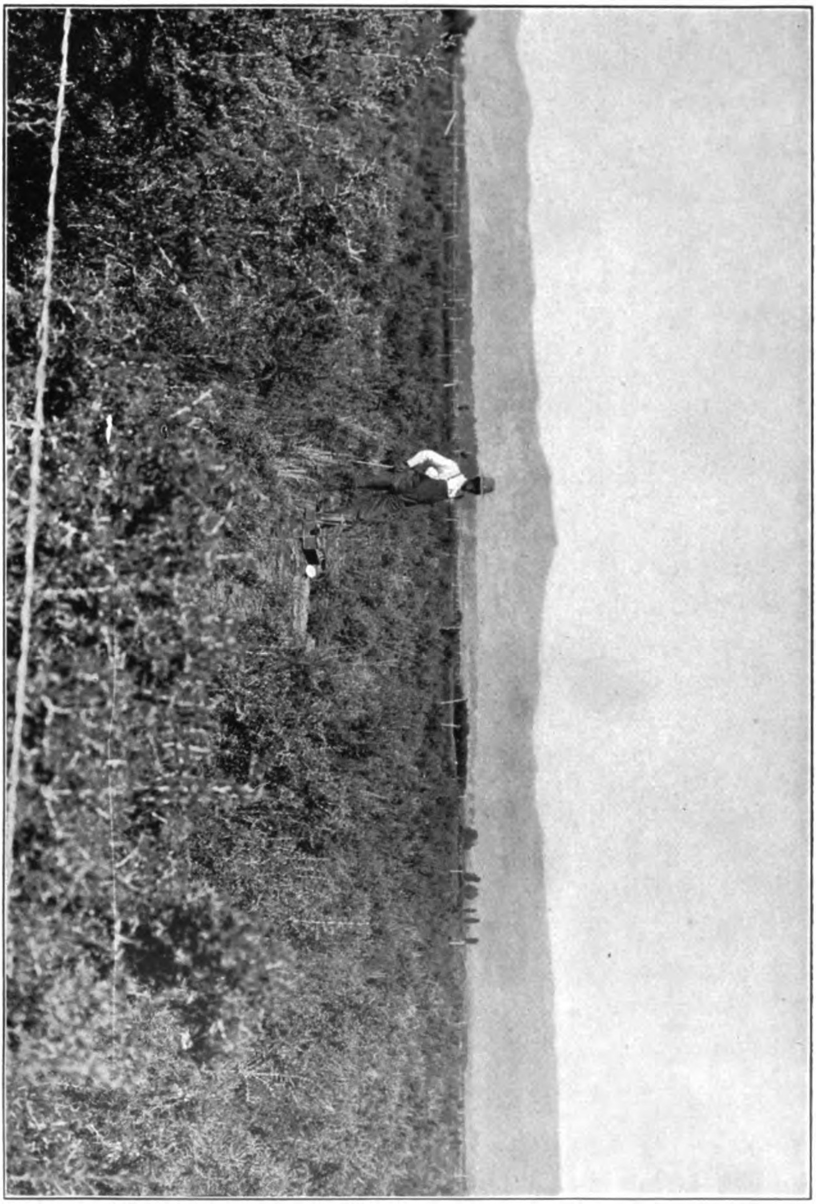
Name of canal.	Capital stock in Otter Creek reservoir.	Percentage of capital stock.	Percentage distribution of Sevier River water when below 101 acre-feet.
Joseph Irrigation Co	$2,454	5.6	10.0
Sevier Valley Canal Co	7,291	16.7	....
South Bend Canal Co	6,734	15.5	....
Monroe Canal Co	5,413	12.4	19.0
Brooklyn Canal Co	2,747	6.3	11.5
Elsinore Canal Co	2,008	4.5	7.0
Richfield Canal Co	11,343	26.0	35.5
Wells Canal Co	1,314	3.0	4.5
Annabella Canal Co	951	2.2	10.5
Vermilion Canal Co	2,108	4.8	....
Rockyford Canal Co	1,201	2.7	....
Isaacson Canal Co	....	....	1.5
Higgins Canal Co	....	....	.5
Total	43,564	....	....

On the San Pitch River, between Manti and Sterling, there is a reservoir which has been used for several years, and, while not so large as the Otter Creek reservoir, it is an important adjunct to the irrigation about Gunnison and Centerfield.

The water for all canals taken from the river above Elsinore is excellent in quality, even in its lowest stage, for irrigating purposes. As is usually the case with river water, it contains least total salts when the volume is greatest, and most when the volume is smallest. In general, the percentage of salts also increases farther down the stream. Sketch maps (figs. 25 and 26) show the depth to standing water and the salt content of irrigation waters in different parts of the valley.

On June 1, 1900, the water from the two upper canals, the South Bend and the Sevier Valley canals, was found to contain 16 parts[1] of salts. Of this, 8 per cent was sodium carbonate (black alkali); 40 per cent was bicarbonate, probably mostly of calcium; 25 per cent was chloride, and the remaining 27 per cent was principally sulphates. Of the bases, lime, as determined later by chemical analyses, constituted more than half. Of these salts, the carbonate is the most injurious, while the bicarbonate is probably the least so. Both the carbonates and the bicarbonates, however, are very unstable, and are readily changed from one to the other.

[1] In this paper parts of salt refer to the parts in 100,000 parts of water.



NATURAL VEGETATION OF GREASEWOOD ON ALKALI LAND.

In water, the presence of much carbon dioxide will convert the carbonates to bicarbonates, while the reverse condition will change them back again. In the soil, conditions of moisture, temperature, and the presence of other salts have a marked influence upon the relation of carbonates to bicarbonates. With good drainage and aeration, the

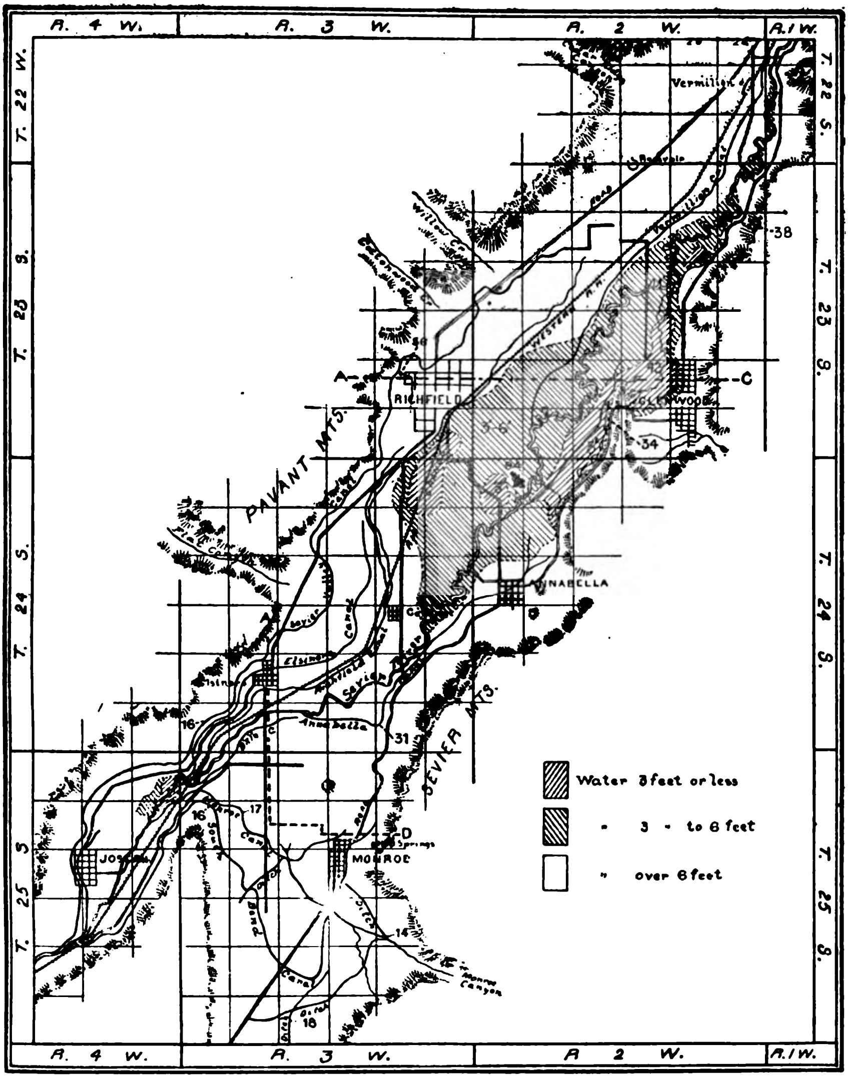


FIG. 25.—Sketch map of Richfield sheet, showing depth to standing water and salt content of irrigation waters in parts per 100,000.

presence of calcium sulphate changes sodium carbonate in part to sodium sulphate, which is much less harmful and which gives rise to carbonate of lime, which is so slightly soluble as to be harmless. The presence of carbon dioxide in the soil is also favorable to the conversion of the carbonates to the bicarbonates.

On the date of the above examination the water from the Brooklyn and Annabella canals was found to carry 32 parts of salt, or twice as much as that of the upper canals. This increase in salts is due to a small amount of seepage, carrying a considerable amount of salts,

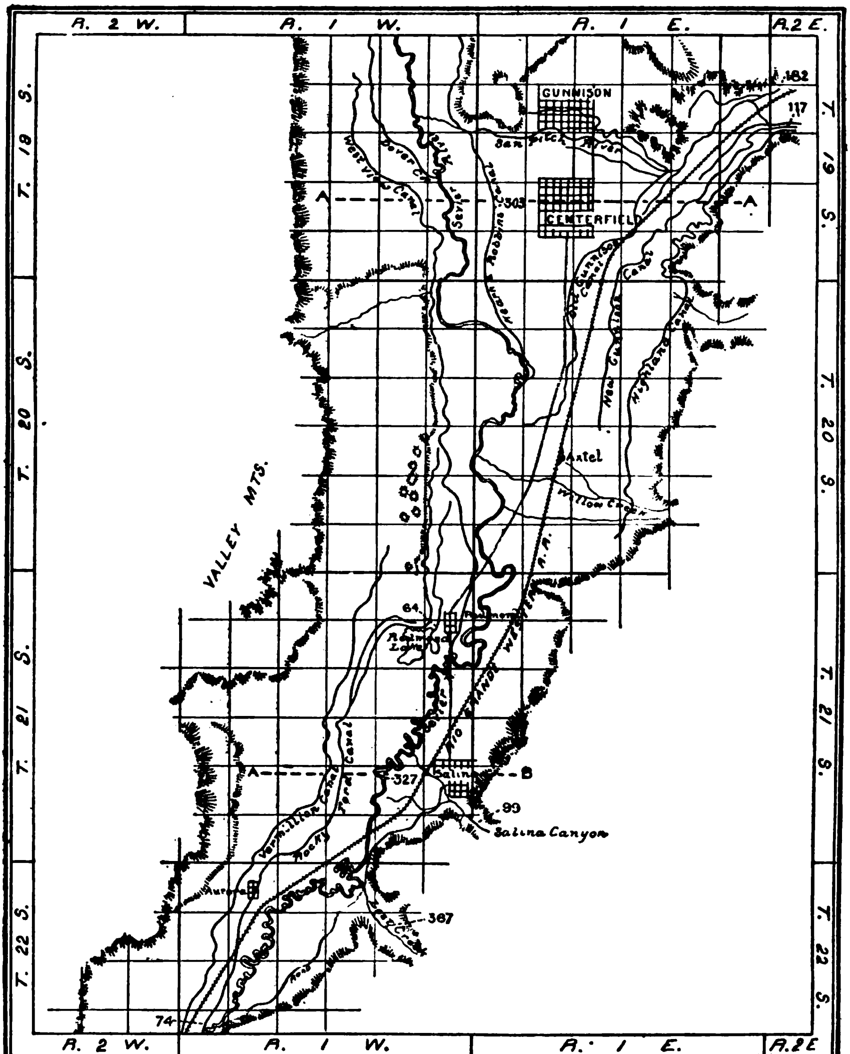


FIG. 26.—Sketch map of Gunnison sheet, showing salt content of irrigation waters in parts per 100,000. (No standing water within 6 feet of surface.)

which enters the river bed from the vicinity of Joseph. Of the total salts in these samples, 65 per cent was bicarbonate. Both seepage waters and well waters of this vicinity are charged with a high percentage of the bicarbonates.

Three weeks later, June 23, the water from the Sevier Valley canal

was again tested and was found to contain 38 parts, against 16 parts the first time. On the same date the water from the Richfield Canal, which is taken from the river at about the same point as the Brooklyn, was tested and was found to contain 49 parts of salts, against 32 parts in the first instance for the Brooklyn.

One month later, July 23, the water of the Richfield Canal was again tested, and was found to contain 57 parts of salts. Although the total salt content had been steadily increasing, there was at this date no carbonate. This was about the last of the water from Otter Creek reservoir, and it was much colored by the presence of moss which had been broken up in the passage of the water down the stony river bed. It is probable that the decomposing moss gave rise to carbon dioxide, which converted the carbonates to bicarbonates.

The canals in this vicinity, namely, the Sevier Valley, Elsinore, Richfield, Joseph, South Bend, Monroe, Brooklyn, and Annabella, appropriate all of the water of the Sevier River during the irrigation season except in times of flood. Three or 4 second-feet, however, are carried through the Annabella Canal and returned to the river farther down where the Vermilion Canal takes up the seepage accumulated below this point.

The Monroe Canyon furnishes water both for irrigation and domestic purposes for the town of Monroe and for some farming lands to the south. The water is exceptionally good, and when tested in June contained only 14 parts of salts, of which three-fourths were bicarbonate. Several miles south of Monroe is a smaller stream which irrigates several farms in the vicinity. The water from this stream contained 16 parts of salts, of which 82 per cent was bicarbonate.

A large spring just southwest of the town of Richfield is the first and only source of irrigation water thus far encountered on the west side of the valley. This spring issues from a limestone crevice in the base of the mountains and furnishes the water supply which irrigates the land around Richfield. The volume of water is 8 or 10 second-feet, and the area that it irrigates is probably not less than 1,000 acres. It has a temperature of 72°, and the small irrigation streams from it run through the town all winter without freezing. Its salt content is 56 parts, of which 80 per cent is bicarbonate.

At Glenwood two large springs rise in the foothills southeast of the town, and at a height approximately 300 feet above the town. They unite and form a stream of considerable size, which furnishes the water supply of the town and irrigates all of the adjacent farms. The water is colder than that from near Richfield and contains less salts. By means of a pipe line enough power could be cheaply generated to furnish light and power for the town of Glenwood, and yet in no way impair the water supply for irrigating purposes.

At the mountain point between Glenwood and Richfield are several large springs which unite and give rise to Cove Creek, which flows

northward and empties into the Sevier River. An attempt has been made to so dam these springs that they would irrigate the land immediately adjacent, but without success. The aggregate volume of water is about 40 second-feet. It empties into the Sevier River and is taken out at Rockyford by the Rockyford Canal, which irrigates the land west of Salina.

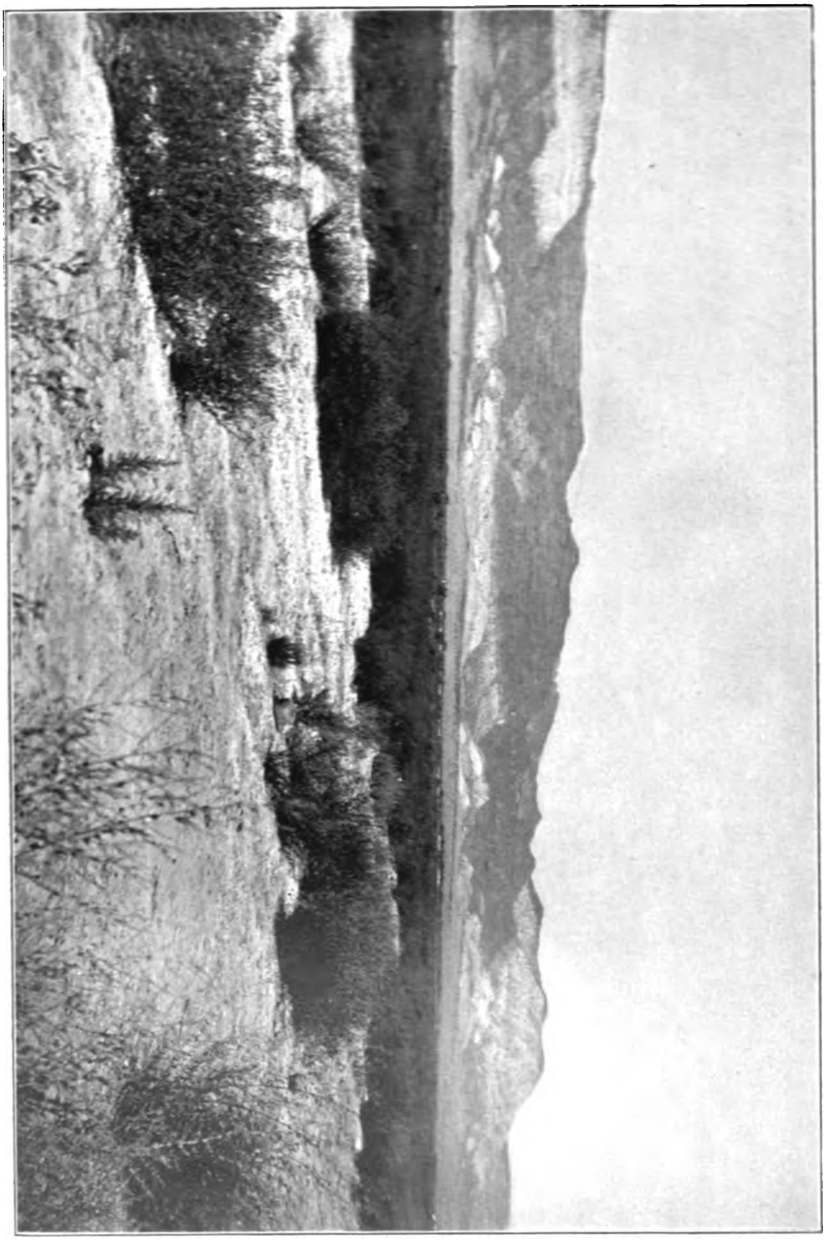
These spring waters are of excellent quality for irrigating purposes and vary but slightly in their character. The water from Cove Creek, which was found to contain 42 parts of salts, represents a little more than the average salt content of the springs, since a small amount of seepage from the Glenwood district joins this creek.

East of Richfield the Vermilion Canal is taken from the Sevier River and furnishes water for irrigating a narrow belt along the river as far north as Salina. The water supply is chiefly seepage, supplemented by 3 or 4 second-feet brought through the Annabella Canal and returned to the river at a short distance above where the Vermilion Canal is taken out. A cross section of this canal would show it to be large, but it has a comparatively small carrying capacity, owing to its slight fall. In July the water was found to contain 77 parts of salts, only a trace being carbonates and 40 per cent being bicarbonates. During 1900 the supply of water for this canal was entirely inadequate to irrigate the land under it, and many of the fields received only one irrigation during the whole season. The head of this canal is in the vicinity where large flows of artesian waters are obtained at a depth of 100 feet or less. Wells flowing one-third of a second-foot can be cheaply obtained, and a number of such wells along the line of the canal would very materially increase its water supply.

Below the intake of the Vermilion Canal a small amount of seepage continues to enter the river channel; several miles farther on this is supplemented by a large volume of spring water entering through Cove Creek. Other springs enter farther on, and the whole volume is taken out at Rockyford Canal, which irrigates a narrow belt of land adjacent to the river, extending northward beyond the town of Redmond. In 1900 this canal had the best water supply in the valley, the volume being constant and continuous throughout the season. An examination of this water in July showed it to contain 74 parts of salts, of which about 40 per cent was bicarbonates.

Beyond the intake of the Rockyford Canal the character or type of alkali changes and the chlorides in both soil and water become first in quantity, while the sulphates are usually second in amount.

Lost Creek is a small tributary which enters the Sevier River 4 or 5 miles south of Salina. Its water is used for irrigating quite a number of farms, but when examined in July it was found to contain 367 parts of salts, of which more than four-fifths were chlorides. Water of such concentration can be used only with great risk, and in a very few years will probably so charge the soils with salts as to make them



ALKALI LAND TOO STRONG FOR CROPS, NEAR RICHFIELD.

unfit for cultivation. This determination was of course made when the volume of water was very low and consequently very salty. When the volume is much larger the salts are of course less in amount, and the accumulation of salts in the soil can then be washed out by the better class of water.

Surface wells in the vicinity showed a salt content of from 200 to 400 parts, of which sodium chloride was also first in amount. The source of these salts is undoubtedly the extensive beds of rock salt found in the mountains just east. These salt beds are usually covered with a layer of salty red-colored soil and the salts are slowly carried to the lower lands by rains.

At Salina the irrigation water is from Salina Creek, which furnishes water for the town and adjacent country. The water supply contained only 100 parts of salt, of which bicarbonates were first in amount. In the soils below the town the chlorides are the chief salts and, indeed, beds of rock salt lie adjacent to the town. The water, unlike the other water examined, carries a high percentage of fine sand and silt which increases its value, for the sand and silt not only fertilize the land but also give to it a surface coating which makes it easy to cultivate and which also serves as a mulch.

The seepage water in the river channel west of Salina was found to contain 328 parts of salts, of which three-fourths were chlorides. A few miles north of Salina the volume of this water becomes sufficient for irrigation and another canal is taken out. Such water, however, can be used only with great risk, and in the course of a few years will load the soils with salts to such an extent as to prevent the profitable growth of crops.

At Redmond there are large springs which give rise to a small lake of the same name. By artificial means the lake has been somewhat enlarged and is used for a storage reservoir. When examined in July, the water, as taken from the lake by an irrigation canal, contained 65 parts of salts, of which 8 per cent was carbonate and 46 per cent bicarbonate. The carbonates have probably been formed from the bicarbonates by the loss of carbon dioxide while standing in the lake.

The next stream of sufficient size to irrigate from is Willow Creek, which enters the valley from the east side. This irrigates only a few farms in the immediate vicinity, and, like most of the small streams, gives an inadequate supply late in the season. The water is good, containing, when low, 104 parts of salts, and the farms irrigated by it bear evidence of successful cultivation.

The next canal, the Kearns & Robbins, is one of considerable size, and is taken directly from the Sevier River. Its water supply is mostly seepage, which accumulates in the river channel from Salina northward; in August it was found to contain 303 parts of salts, of which chlorides and sulphates were the chief constituents. Much of the land under this canal in its virgin state was very salty, and it has

taken several years of irrigation with this class of water to bring the land into condition for growing alfalfa. Where irrigation water is used freely on greasewood land this vegetation disappears and salt grass takes its place. The land is then used for pasturage or meadow for a few years, after which, if irrigation waters have been used liberally, the land can be broken up and seeded to oats or barley and subsequently to alfalfa. The water usually contains less salts than the 303 parts found in August, as mentioned above, and in a measure corrects the land for the large amount of salts put on by the water when in the condition shown by the above determination.

The West View Canal, taken out on the west side of the Sevier River below the Kearns & Robbins, is the last canal taken out in this area. For this reason its water supply is very poor. The condition of the farms under this canal show that farming here is a struggle against adverse conditions.

The towns of Gunnison and Centerfield, and a large body of land in their vicinity, get their water supply from the San Pitch River and its tributaries. On the river just below Manti is a large reservoir for storing water for this district. When in August this part of the valley was surveyed, the reservoir was dry and the normal flow in the river was very low and contained 182 parts of salts. The flow in Twelvemile Creek, which joins the San Pitch River about 3½ miles east of Gunnison, was also low and carried 117 parts of salts. In Twelvemile Creek the chlorides predominate, while in the San Pitch River chlorides, sulphates, and bicarbonates are found in about equal quantity.

The water supply from this source irrigates a large area of land in this part of the valley, but does not furnish sufficient water for all the good land. There are good sites for more reservoirs, however, and by utilizing them, all of the land north of Willow Creek west to the Sevier River could be irrigated.

The water from a large number of surface wells scattered throughout the district was examined and showed that commonly surface well waters are very salty, the amount of salts varying from 60 to 400 parts. The character of these salts usually corresponds with the salts of the soils in the same vicinity. In the upper part of the valley, about Joseph, Monroe, Elsinore, Richfield, and Glenwood, bicarbonates are first in amount in well waters, while about Lost Creek and Salina the chlorides are much greater than all the other salts combined. At Gunnison and Centerfield the wells invariably show a high percentage of salts, of which sulphates form the greater part. Usually the higher the total salts the smaller the relative amounts of bicarbonates. Normal carbonates are never present in well, spring, or artesian waters, but any of these, upon standing for some time in ponds, reservoirs, or canals, may show carbonates. This change is probably brought about by the loss of carbon dioxide from the water.

The following tables give the field determinations of the salts in a large number of samples of water from canals, springs, wells, artesian wells, and seepage from all parts of the district. The total salts were determined by the electrolytic method; the carbonates and bicarbonates were determined by titrating with tenth normal acid potassium sulphate in the presence of phenolphthalein first and then of methylorange; the chlorides were determined by titrating with tenth normal silver nitrate in the presence of potassium chromate, and the sulphates were determined by difference. It will suffice to say that these analyses represent the condition at the time the survey was made—June to August, inclusive. This represents the important part of the irrigation season, but it is recognized that the year was one of unusual drought, and as a consequence the determinations of the salt content of the waters are probably generally slightly above the normal. When the water supply is most abundant, the percentage of salts is generally lowest, the percentage increasing as the water supply diminishes.

Salts in 100,000 parts of water, as determined in the field, Sevier Valley.

Field No.	Source of water, location, and date of determination.	Carbonates.	Bicarbonates.	Chlorides.	Sulphates.	Total.
	Water from canals.					
34	Sevier Valley Canal, June 4, 1900	0.8	6.8	3.5	4.5	15.6
29	South Bend Canal, June 1, 1900	1.9	6.0	4.6	4.4	16.9
30	Monroe Canal, June 1, 1900	.5	7.9	3.5	5.2	17.1
58	Annabella Canal, June 6, 1900	4.2	19.9	7.1	.0	31.2
36	Brooklyn Canal, June 4, 1900	Tr.	21.2	9.0	2.3	32.5
175	Sevier Valley Canal, June 23, 1900	2.1	26.7	5.8	4.0	38.6
174	Richfield Canal, June 23, 1900	1.0	30.7	5.8	11.6	48.8
368	Richfield Canal, July 23, 1900	.0	34.0	11.6	11.3	57.4
358	Rockyford Canal, July 20, 1900	2.6	29.0	27.8	15.0	74.4
275	Vermilion Canal, July 7, 1900	Tr.	34.0	18.6	24.4	77.0
431	Kearns & Robbins Canal, August 7, 1900	2.1	16.6	194.9	89.4	303.0
434	Gunnison Canal, August 14, 1900	Tr.	63.1	85.8	50.2	199.1
	Mean	1.3	24.7	31.5	18.6	76.0
	Spring waters.					
266	Glenwood Springs	....	18.3	1.7	.1	20.1
235	Point of mountain west of Glenwood	....	25.7	5.8	2.4	33.9
335	Butte south of Vermilion	....	26.6	7.0	3.9	37.5
272	Point of mountains west of Glenwood (east side)	....	28.2	7.5	4.2	39.9
196	Richfield Spring	....	46.5	4.6	4.5	55.6
414	Redmond Springs	5.3	30.7	24.4	4.2	64.6
171	Monroe Hot Springs	5.3	53.1	119.5	89.9	267.7
	Mean	1.5	36.4	24.4	15.6	74.2
	Streams.					
86	Monroe Canyon, June 11, 1900	Tr.	10.8	1.2	2.3	14.3
108	Small stream south of Monroe	1.0	14.9	2.3	....	18.2
259	Cove Creek, July 6, 1900	3.2	26.6	10.4	2.3	42.5
372	Salina Creek, July 23, 1900	2.1	40.7	33.6	12.6	99.0

Salts in 100,000 parts of water, as determined in the field, Sevier Valley—Cont'd.

Field No.	Source of water, location, and date of determination.	Carbonates.	Bicarbonates.	Chlorides.	Sulphates.	Total.
	Streams—Continued.					
409	Willow Creek, July 23, 1900	5.3	43.2	36.0	19.9	104.4
449	Sterling coal mine, August 22, 1900	0.0	50.5	3.5	10.4	64.4
450	Sixmile Creek, August 22, 1900	3.7	32.5	1.2	2.2	39.6
437	Twelvemile Creek, August 14, 1900	.8	47.3	34.8	33.7	116.6
436	San Pitch River, August 14, 1900	3.7	54.4	95.1	31.2	182.4
389	Lost Creek, July 30, 1900	3.2	13.3	298.1	52.6	367.2
352	Small stream south of Vermilion	Tr.	37.3	1,097.2	22.5	1,156.0
	Mean	2.1	33.8	146.7	17.3	200.0
	Artesian wells.					
277	Bolithos, 95 feet deep, 2 miles E. of Richfield		33.2	5.2	5.1	43.5
276	Bolithos, 82 feet deep, 2 miles E. of Richfield		31.5	9.3	9.1	49.9
316	Pump well, sec. 16, T. 23 S., R. 2 W		44.8	4.6	1.5	50.9
280	Segmiller well, 2¼ miles E. of Richfield		29.0	17.4	10.6	57.2
267	Glenwood, 69 feet deep		56.4	9.3	4.8	70.5
251	Sec. 29, T. 23 S., R. 2 W		59.8	10.4	8.1	78.4
242	Sec. 31, T. 24 S., R. 2 W		27.4	44.1	20.3	91.8
	Mean		40.3	14.3	8.5	63.1
	Driven wells.					
391	Sec. 9, T. 22 S., R. 1 W		24.9	116.0	82.1	223.0
74	Sec. 23, T. 24 S., R. 3 W., 50 feet		88.0	32.5	129.0	249.6
392	Across road from 391, 85 feet		49.8	183.3	182.0	415.0
	Mean		54.2	110.6	131.0	295.8
	Surface wells.					
103	Sec. 12, T. 25 S., near river, 6 feet to water		42.3	5.8	8.8	56.9
43	Sec. 14, T. 25 S., R. 4 W., 30 feet to water		30.7	5.8	24.1	60.6
56	Sec. 34, T. 24 S., R. 3 W., 22 feet to water		55.6	9.3	11.2	76.1
182	Sec. 18, T. 24 S., R. 2 W., 8 feet to water		68.9	10.4	16.0	97.3
369	White house well, Salina		93.8	13.9		100.4
166	Sec. 13, T. 24 S., R. 3 W		85.5	30.2	38.1	153.8
429	Sec. 29, T. 19 S., R. 1 E., 31 feet to water		78.8	63.7	49.5	195.6
425	Sec. 20, T. 19 S., R. 1 E., 20 feet to water		97.9	75.4	44.7	218.0
421	Christensen house, 12 feet to water		93.8	58.0	82.0	233.8
433	Robbins ranch		90.5	80.0	74.5	245.0
93	Sec. 1, T. 25 S., R. 4 W		45.6	161.2	90.0	296.7
445	Sec. 4, T. 20 S., R. 1 E., 65 feet to water		36.5	134.5	208.7	379.7
200	Sec. 12, T. 24 S., R. 3 W		72.2	150.8	261.1	484.1
	Mean		68.6	61.5	69.7	199.8
	Seepage.					
33	Near river, 2 miles SW. of Elsinore		24.6	30.2	28.5	83.3
136	Near river at Annabella		70.0	12.0	12.0	94.0
379	Sevier River at Salina		17.8	238.9	70.9	327.6
458	Drainage from Robbins ranch	4.2	17.0	232.0	97.0	350.2
	Mean	1.0	32.4	128.3	52.1	213.8

Sevier Valley irrigation waters.

COMPOSITION.

[Parts in 100,000 parts of water.]

Constituent.	Sevier Valley Canal at Elsinore, June 23.	Richfield Canal at Elsinore, June 23.	Rockyford Canal at Salina, July.	Gunnison Canal east of Gunnison, August.	Monroe Hot Springs, Monroe, June 23.	Seepage at river near Central, June 19.
Ca	6.4	7.6	6.4	6.5	29.7	7.1
Mg	1.3	2.0	2.9	8.9	3.9	4.9
Na	2.9	4.0	10.1	13.5	54.6	9.2
K	1.1	0.9	2.1	4.6	5.1	0.9
SO_4	5.9	7.2	11.6	35.6	93.2	11.1
Cl	3.5	7.0	16.9	15.5	66.7	7.0
CO_3	2.7	3.0	0.0	0.0	2.7	5.1
HCO_3	16.6	20.0	20.3	35.7	24.8	36.1
Total	40.4	51.7	70.3	120.3	280.7	81.4

THEORETICAL PERCENTAGE COMBINATION.

Constituent.	Sevier Valley Canal at Elsinore, June 23.	Richfield Canal at Elsinore, June 23.	Rockyford Canal at Salina, July.	Gunnison Canal east of Gunnison, August.	Monroe Hot Springs, Monroe, June 23.	Seepage at river near Central, June 19.
$CaSO_4$	20.54	19.62	23.32	18.38	35.93	19.29
$MgSO_4$				20.78	6.88	
Na_2SO_4					3.46	
CaCl			6.26			
MgCl			16.07	12.63		
KCl	5.20	3.27	5.69	7.31	3.46	2.09
NaCl	10.15	19.62	8.82		36.49	12.53
$Ca(HCO_3)_2$	40.10	35.76				12.41
$Mg(HCO_3)$	2.97	13.65				21.37
$NaHCO_3$	11.63		39.84	40.90	12.14	23.59
$MgCO_3$	9.41	8.08				8.72
Na_2CO_3					1.64	

Water containing less than 150 parts of salts can be used with safety for irrigating purposes, except when the salts are largely sodium carbonate. When more than 150 parts of salts are present, care should be exercised in the management and application of the water. Three hundred parts of salts may be taken as the extreme limit for irrigation purposes, above which it is never safe to go except in cases of emergency on good lands, where one or two applications of salty water may be used if good water can afterwards be obtained to wash the salts out or down. With a salt content of from 250 to 300 parts the best results can never be obtained, and great danger accompanies the constant use of this class of water.

Of the various salts usually present in either soil or irrigation water the carbonates and chlorides are the most harmful, while the sulphates and bicarbonates are least so. The lime sulphate, especially when sodium carbonate is present in the soil, is beneficial; in limited amounts it is also helpful in the presence of the chlorides. In the former case the sodium carbonate is partly converted to sodium sulphate, with the resulting calcium carbonate, which is so slightly

soluble as to be harmless. In the case of chlorides, sodium chloride is converted in part into calcium chloride, which is less harmful than the former, and which, in small amounts, has a stimulating effect upon plants.

APPLICATION OF WATER.

Water in Sevier County being scarce, the farmers irrigate their fields by the furrow method, which consists in running parallel furrows from 3 to 4 inches in depth at intervals of from 2 to 2½ feet down the slope of the field and then turning the water into these furrows. This has two chief advantages over the flooding system, namely, greater economy of water and the doing away of the necessity of leveling of fields. In the case of alkali soils, or when the irrigation water carries much salts, the flooding method is better. Furrow irrigation leaves the salts on the ridges and its accumulation is often sufficient to do much damage. Flooding washes the whole surface and carries the salts down, and when the water goes sufficiently deep they pass beyond the zone of active root growth and do no harm. Successful irrigation by flooding requires level fields, and level fields for grain and alfalfa are preferable, as they are much easier to harvest and also insure a better distribution of water to the small plants.

In the application of water, especially on loose, sandy soils and on sandy loams where the underlying stratum is of the same or perhaps even more porous character, great care should be exercised not to run water over fields for too long a distance. When this is done a great loss of water often occurs, for the water sinks into the ground so rapidly that the portion of the field nearest the ditch is often overirrigated before the water reaches the lower part of the field. For the most economical use of water the land should be well leveled and a good-sized volume of water used for irrigating. The distance over which to run water should be short, so that the whole of the area can be quickly covered and thus give all parts as nearly as possible an equal time in which to become wet. Too much water is harmful, not only to the area to which it is applied, but often to lands at a lower level. Lowlands may be, and often are, ruined for all agricultural purposes by the accumulation of alkali and seepage water caused by the overirrigation of lands at higher levels.

How much water to apply at an irrigation and how frequently to irrigate are problems which have not been thoroughly investigated. Obviously, both of these questions will depend upon a number of factors; for example, the kind of soil, the character and stage of growth of the crop, and the climatic conditions of rainfall and rate of evaporation. So long as water does not pass beyond the roots of the crops and become lost to them, heavy irrigation, with long intervals between, is the most economical of water. Frequent irrigation with

small amounts of water is wasteful because of the relatively larger amount of water which evaporates directly from the ground surface. Shallow irrigation is also conducive to shallow root growth, which condition does not allow the plants to withstand drought.

A large number of observations in a great many States and on all types of soil has brought out the fact that when the most favorable moisture content for plant growth is diminished by 25 per cent the soil becomes too dry, and when increased by the same amount it is too wet, for the most favorable results. This, therefore, gives us a basis on which to estimate the amount of water required for an irrigation.

A medium sandy loam, having about 12 per cent of clay, will contain under the most favorable condition about 16 per cent of its dry weight of moisture. When this amount of moisture is decreased by 25 per cent, that is, when it falls to 12 per cent of the dry weight of the soil, then drought begins and the soil needs irrigation. When the normal moisture is increased by 25 per cent, that is, raised to 20 per cent of the dry weight of the soil, irrigation should cease, for beyond this amount the soil becomes too wet for favorable plant growth. In case of a medium sandy loam, therefore, we have a range of 8 per cent in moisture, extending from 12 to 20 per cent of the dry weight of the soil, in which the moisture conditions are favorable to plant growth and above and below which they become unfavorable. When the lower limit is reached, irrigation should begin and be continued until the upper limit is reached; in other words, the soil moisture should be increased 8 per cent. Assuming that the soil needs irrigating to a depth of 4 feet and that a cubic foot of dry sandy loam weighs 85 pounds, it would require $4 \times 85 \times 0.08$, or 27.2 pounds of water to each square foot of surface. This is equal to an irrigation of 5¼ inches of water over the entire surface of the field. Allowing three-fourths of an inch for loss by evaporation from the water during irrigation and from the excessive wet surface for a short time thereafter, it seems quite safe to say that under the above conditions 6 inches of water would be required at an irrigation. No rule can be given as to how frequently such an irrigation should be repeated, because so much depends upon the climatic conditions, the kind of crop, and its stage of growth. In order to apply the usual amount of water estimated for a season's irrigation, that is, 2½ feet of water, such irrigation in order to cover a period of four months should be made at intervals of twenty-four days.

The loss of water by evaporation and seepage during its transit through canals, laterals, and ditches to the land to be irrigated is in many cases enormous, and every means not entailing undue expense should be resorted to in order to reduce this loss to a minimum. Many cases are reported where only one-fourth of the supply from streams ever reaches the land to be irrigated. In the older and more

valuable irrigated districts water-tight pipe lines or cement ditches are used, at considerable expense, to conduct the water to the lands. The value of water will necessarily increase in the Sevier Valley and more expensive and better means must be used for its conservation.

In the construction of canals the chief point to guard against is loss by seepage. When run over sandy or gravelly soils the loss of water from this source is often enormous. If the water to be used is at times laden with silt, the leaky canals may soon become lined with fine material and thus stop the leakage, but if clear water only is used the leaks may continue for an indefinite time. Canals when built on this character of soil should be well puddled, a good way of puddling being to drive a flock of sheep or goats through the canals while they are wet.

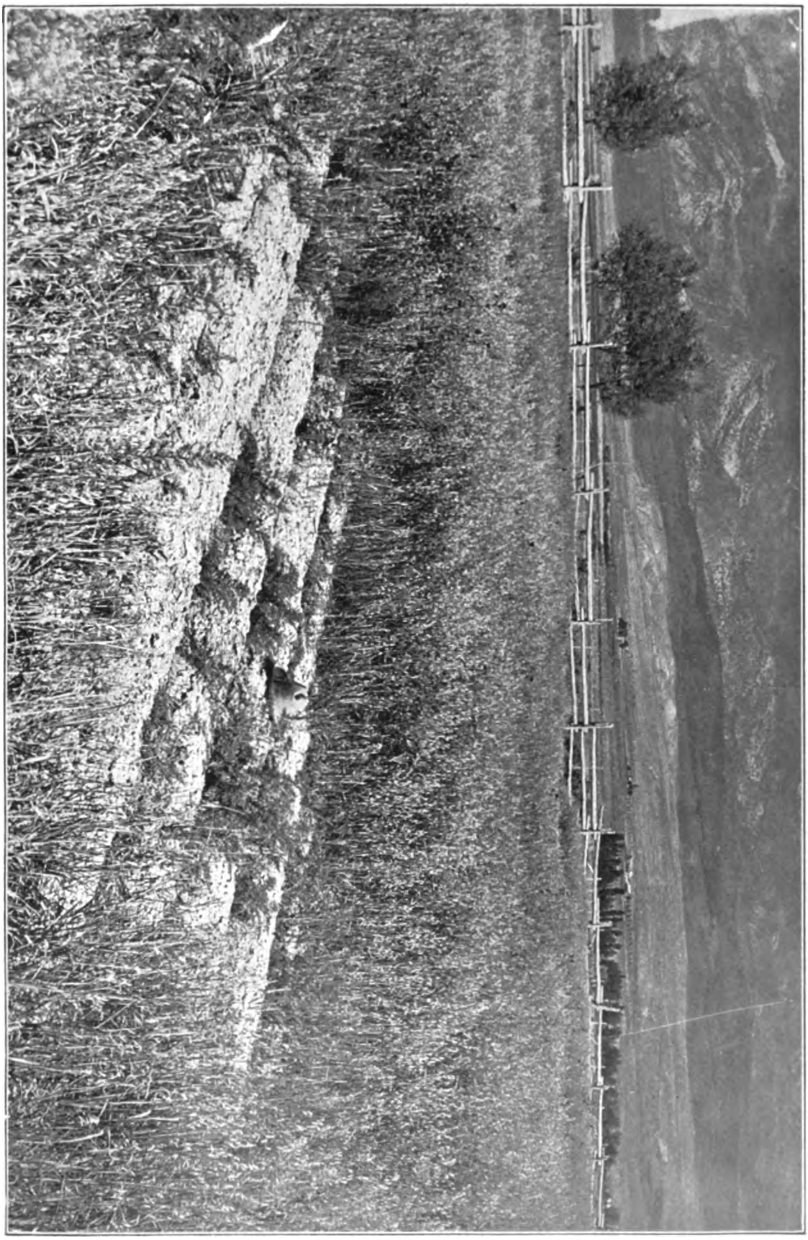
Level canals, having a slow water movement, often become filled to such an extent with growing moss as to nearly stop the flow of water. In cases of this kind the moss should be removed, and there are two ways in which this can be readily accomplished—either by letting all the water out of the canal for a day or two when there is bright sunshine, thus killing the moss, which will cause no trouble when the water is turned in again, or by running a disk harrow the length of the ditch. This disk harrow agitates the mud, entangles it with the moss, and on settling it carries the moss to the bottom of the canal, where it does no harm.

ALKALI.

In most Western soils there is a sufficient amount and often a superfluity of soluble salts. Indeed, some of the soils in the Sevier Valley are entirely crusted with salts, which must be washed out before crops can be grown. The usual forms of alkali are the chlorides, sulphates, carbonates, and bicarbonates, especially the latter. The chlorides are more in evidence in the lower part of the valley than in the upper part, owing to the very large amount of rock salt (halite) found near Salina and Redmond. Chlorine is not found to a large extent in the artesian wells nor in the canals, so it has undoubtedly come from the mountains, where sodium chloride exists in beds formed from the early salt waters. The normal carbonates are not present in large quantites, but, on the contrary, the bicarbonates are found everywhere, usually in abundance.

The action of bicarbonates on plants is being examined in the Division of Soils at present and will be made the subject of an extended report. It is quite likely they are not so harmful as many of the other forms of white alkali; nevertheless, as will be shown, their presence is obnoxious.

Mr. Lyman J. Briggs, of the Division, has shown that soil has the power of absorbing and retaining a much larger proportion of carbon dioxide than there is present in the air. The action of carbon dioxide in water on magnesium and calcium carbonates ($MgCO_3$ and $CaCO_3$)



ALKALI SPOT REMAINING IN GRAINFIELD WHICH HAS BEEN RECLAIMED FROM ALKALI THROUGH ORDINARY IRRIGATION.

The soil of such spots has a greasy feel and water does not enter it readily to leach out the alkali, but simply flows over the surface.

partially dissolves those minerals with the formation of their bicarbonates, as $Ca(HCO_3)_2$.. But these salts dissociating, the HCO_3 group will react with the common salt (NaCl) and sodium sulphate (Na_2SO_4), forming bicarbonate of sodium ($NaHCO_3$).

The foregoing reactions may be thus expressed:

$$CaCO_3+CO_2+H_2O=Ca(HCO_3)_2$$
$$Ca(HCO_3)_2+Na_2SO_4 \leftrightarrow CaSO_4+\underline{NaHCO_3}$$
$$Ca(HCO_3)_2+2NaCl \leftrightarrow CaCl_2+\underline{NaHCO_3}$$

The latter product (sodium bicarbonate) is the salt so abundant in the waters and soils in the Sevier Valley, and being quite soluble, is carried everywhere by the water. When the water stands exposed to the air, as, for example, when standing on the surface of the ground around artesian wells or on the ground after irrigation or in ditches, etc., the pressure of the carbonic acid in the air being less, the bicarbonate breaks up to some extent, giving off carbonic acid, the following reaction takes place to a certain extent:

$$2NaHCO_3=\underline{Na_2CO_3}+CO_2+H_2O$$

The underscored is the black alkali, or sodium carbonate. This result can be seen on the banks of almost any ditch or canal in Sevier Valley, around the artesian wells, and around pools of water standing in the road. The water itself may have no normal carbonate when applied, but a black surface is formed on the soil after the water has stood, due to the change above noted.

There is a large amount of gypsum ($CaSO_4$) present in the soil, which under favorable conditions, according to the following equation, would change to a great extent the black alkali to the white, a less dangerous form of alkali:

$$CaSO_4+Na_2CO_3 \rightleftarrows CaCO_3+Na_2SO_4$$

But the existing conditions will not permit a complete change to take place, and even if it went on very rapidly there is constantly a large reserve of bicarbonates being continuously drawn upon to form more black alkali. As these irrigation waters and artesian wells all contain bicarbonates, it is obvious that water must be applied to the soil with judgment, or the alkali conditions will gradually become worse.

The alkali maps show the condition of the whole district as regards the percentage of soluble salts present in the upper 5 feet of soil when at water saturation. These maps should be of great value to the landowners of the district and also to prospective settlers in showing just what lands are sufficiently free from alkali to be cultivated with safety, the lands that have only moderate amounts of alkali and require great care in cultivation, and the lands undoubtedly too salty to produce crops until the salts have in part been removed.

All areas showing less than 0.2 per cent of salts may be considered safe for all kinds of farm crops, and there will never be any danger from alkali so long as good water is used and the land is well drained. In case of poor drainage, the water table rising within 3 feet or less of the surface, there may be a sufficient accumulation of the salts at the immediate surface to kill crops and yet the percentage in the upper 5 feet not exceed 0.2 per cent.

The areas having from 0.2 to 0.4 per cent are, with few exceptions, risky to cultivate, and under the most favorable conditions the fields of grain and alfalfa invariably show spots where the crops either fail entirely or make only a feeble growth. It must of course be borne in mind that when near the lower limit of this range the conditions may be quite good if the salts are well distributed or are mostly in the lower depths. On the other hand, if the upper limit is approached and the salts are massed at the surface the conditions may be such as to entirely prevent the growth of crops. When the average salt content is above 0.4 per cent the lands are never safe to cultivate in any of our ordinary farm crops. With from 0.4 to 0.6 per cent sweet clover may be grown which will produce a large growth of forage of rather poor character, but if harvested very early it will produce fairly good fodder for cattle. The growth shades the ground surface and the roots add organic matter and nitrogen to the soil, all of which tend to lessen the deleterious effects of the alkali, although it may not actually reduce the percentage of salts present.

A summing up of the alkali map shows that 100,900 acres, or 72.9 per cent of the area surveyed, have less than 0.2 per cent of salts and are perfectly safe to cultivate. In the upper portion of the valley about Joseph, Monroe, and Elsinore practically all of the land falls in this class. Here the water is of excellent quality, the drainage is good, and a larger percentage of the land is under cultivation than elsewhere in the valley.

The following table shows the acres and percentage of the land variously affected by alkali:

Salt content, per cent.	Areas in acres.	Percentage of whole area.
.0-0.2	100,900	72.9
.2-0.4	11,800	8.5
.4-0.6	13,000	9.4
.6-1	10,700	7.7
1.0-3	2,100	1.5

As a rule, the alkali lands occur in the lower and more level portions of the valley, where the drainage is poor and where the soils are more apt to be of a heavy texture. In the virgin state, dry lands with good drainage invariably show an increase in salt content as the depth

increases, while the reverse is true if the lands are wet and subject to excessive evaporation. In a general way this also applies to cultivated lands.

KINDS OF ALKALI.

The following table shows the percentage composition of 13 crusts collected from various parts of the district:

Chemical composition of salts in crusts and soils.

No.	Description.	Per cent soluble.	Ca.	Mg.	Na.	K.	SO_4.	Cl.	CO_3.	HCO_3.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4716	White alkali crust near Warm Springs, Joseph.	18.63	3.08	0.18	31.34	1.40	32.23	31.25	0.03	0.39
4717	White alkali crust, 1¼ miles SW. of Richfield.	24.87	1.74	6.26	22.71	.41	44.81	22.86	......	1.21
4718	White alkali crust, 1¼ miles SE. of Richfield.	21.51	2.19	6.28	22.94	.34	38.91	28.78	......	.56
4719	Crust from Hot Springs at Monroe	37.33	1.78	.48	30.04	1.88	50.91	14.33	.39	.19
4721	Crust from edge of furrow at Central	2.01	3.98	.60	22.97	6.36	12.23	23.76	......	30.11
4722	White alkali crust, 1¼ miles NE. of Monroe	5.27	2.62	.42	27.88	1.44	54.20	2.66	1.82	8.96
4723	White alkali crust	3.03	5.55	Tr.	24.58	3.24	35.02	8.13	5.28	18.17
4724	Black alkali crust, one-fourth mile N. of SE. C. sec. 3, T. 24 S., R. 3 W.	5.04	1.55	.32	31.28	2.86	17.68	33.46	.36	12.49
4725	Alkali crust from nook along river, Elsinore	36.99	.05	Tr.	36.82	1.10	15.85	44.72	.81	.05
4890	Crust, C. of SE. ¼ sec. 2, T. 24 S., R. 3 W.	24.85	1.96	1.96	29.66	.70	37.21	27.29	......	1.22
4909	Crust, W. C. sec. 10, T. 23 S., R. 2 W., largely chlorides	5.80	9.34	7.71	15.05	1.77	5.27	58.28	......	2.58
4920	Brown crust, ¼ W. of N. C. sec. 29, T. 23 S., R. 2 W.	14.98	13.52	3.43	18.04	.71	5.61	57.48	......	1.21
4951	Crust, 0 to one-half inch	50.97	1.68	2.56	29.98	.67	25.48	39.03	......	.30
	Mean	......	3.72	2.35	26.41	1.76	28.88	30.16	.67	6.00

The above table shows the bases and acids as actually determined, and the following table gives the theoretical combination of these bases and acids:

Theoretical percentage combination.

No.	Description.	$CaSO_4$.	$MgSO_4$.	Na_2SO_4.	K_2SO_4.	$CaCl_2$.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
4716	White alkali crust near Warm Springs, Joseph	10.46	0.90	35.71	....	....
4717	White alkali crust, 1¼ miles SW. of Richfield	5.91	31.00	23.53	....	....
4718	White alkali crust, 1¼ miles SE. of Richfield	7.46	31.10	13.05	....	....
4719	Crust from Hot Springs at Monroe	6.08	2.37	66.19	....	....
4721	Crust from edge of furrow at Central	13.52	3.27	....	....	....
4722	White alkali crust, 1¼ miles NE. of Monroe	8.89	2.05	68.51	....	....
4723	White alkali crust	18.84	....	32.11	....	....
4724	Black alkali crust, one-fourth mile N. of SE. C. sec. 3, T. 24 S., R. 3 W	5.27	1.55	18.95	....	....
4725	Alkali crust from nook along river, Elsinore	.18	....	23.26	....	....
4890	Crust, C. of SE. ¼ sec. 2, T. 24 S., R. 3 W	6.63	9.77	35.34	1.55	....
4909	Crust, W. C. sec. 10, T. 23 S., R. 2 W., largely chlorides	7.44	....	....	....	19.80
4920	Brown crust, ¼ W. of N. C. sec. 29, T. 23 S., R. 2 W.	7.94	....	....	....	30.92
4951	Crust, 0 to one-half inch	5.69	14.16	13.84	1.49	....
	Mean	8.08	7.40	25.42	.23	3.90

Theoretical percentage combination—Continued.

No.	Description.	$MgCl_2$.	NaCl.	KCl.	Na_2CO_3.	$NaHCO_3$.
4716	White alkali crust near Warm Springs, Joseph		49.51	2.65	0.23	0.54
4717	White alkali crust, 1¼ miles SW. of Richfield		37.11	.78		1.67
4718	White alkali crust, 1¼ miles SE. of Richfield		46.99	.64		.76
4719	Crust from Hot Springs at Monroe		20.84	3.58	.68	.26
4721	Crust from edge of furrow at Central		29.62	12.14		41.45
4722	White alkali crust, 1¼ miles NE. of Monroe		2.24	2.73	3.23	12.35
4723	White alkali crust		8.59	6.15	9.32	24.99
4724	Black alkali crust, one-fourth mile N. of SE. C. sec. 3, T. 24 S., R. 3 W		50.95	5.43	.63	17.22
4725	Alkali crust from nook along river, Elsinore		72.15	2.10	1.42	.89
4890	Crust, C. of SE. ¼ sec. 2, T. 24 S., R. 3 W		45.04			1.67
4909	Crust, W. C. sec. 10, T. 23 S., R. 2 W., largely chlorides	30.23	35.66	3.30		3.57
4920	Brown crust, ¼ W. of N. C. sec. 29, T. 23 S., R. 2 W	13.45	44.67	1.35		1.67
4951	Crust, 0 to one-half inch		64.41			.41
	Mean	3.36	39.06	3.14	1.19	8.27

All of these samples showed carbonates when tested in the field, but the laboratory examination shows only six out of the thirteen to contain carbonates. By comparing the percentage of the crust that went into solution, when 50 grams were placed in a liter of water, with the column giving the percentage of bicarbonates, we find that the latter are very much higher where the crusts were not concentrated, and that where the crusts went largely into solution the bicarbonates comprise only a small percentage of the total salts. This was noticeable throughout the field determinations of the district. Wherever salts of either soils or waters were present in small or only moderate amounts bicarbonates were first in amount, but when the alkali conditions became bad the relative amount of the bicarbonates became smaller while the chlorides or sulphates increased. Throughout the southern half of the Richfield district bicarbonates predominate and are equal to fully one-half of all the salts present. From Glenwood northward to Redmond chlorides predominate, especially on the east side of the valley, while the sulphates are second in amount. From Redmond northward bicarbonates again become first in amount, except along the lowlands adjacent to the river.

A large number of determinations throughout the district shows black alkali (Na_2CO_3) to be nearly always present, but usually in small amounts. Of a hundred or more determinations only six showed more than 0.1 per cent of black alkali, and in five of these the total salt content was greater than 0.5 per cent. The determination showing black alkali as the source of trouble represents only a small local spot.

Throughout the district, lime and magnesia carbonates are very plentiful and are responsible for the large percentage of bicarbonates that are so frequently present.

The source of the alkali is from the decomposing rocks and from

beds of rock salt that exist in various places along the mountains. There is not sufficient rainfall to carry these salts out of the valley, but they are frequently moved for some distance and massed either in wet, poorly drained areas or in heavy soils.

As a rule, the lands are so well underdrained that when irrigated the salts are gradually carried away and do no harm. From Richfield northward, however, there is considerable lowland bordering on the river in which the drainage is not always good. It is in these soils that the alkali is usually worst, and here also the problem of getting rid of it is most difficult. Where the natural drainage is poor artificial drainage should be resorted to as the means of carrying away the alkali when the land is irrigated.

SEEPAGE.

The seepage waters of the southern half of the district are, as a rule, not heavily charged with salts, but that which finds its way into the river from Salina northward is quite salty. The largest amount of damage done by seepage is in the vicinity of Richfield and Glenwood. The sketch map on page 269 shows 2,500 acres here which have standing water within 3 feet or less of the ground surface, and 10,500 acres in which the water is within from 3 to 6 feet of the surface. In the vicinity of Richfield the Richfield Canal leaks considerably, and there is undoubtedly much seepage from the land irrigated both by this canal and by the two canals which are situated above it. It is from this same source that the lands immediately south of the town are made wet. By far the greater part of the wet land, however, is caused by numerous springs which occur all along the base of the mountains, both north and south of Glenwood. These springs keep the flat land of the vicinity saturated with water and cause an accumulation of salts at the surface. While much of this land is underlaid by a porous sand, which under ordinary circumstances would afford good drainage, yet the land here is so level and the supply of water which causes the damage is so plentiful that the land is always wet. A few large ditches to conduct the water from these springs, instead of allowing it to soak into the adjacent lands, would make a marked change in the condition of this neighborhood.

SOIL SURVEY IN SALT RIVER VALLEY, ARIZONA.

By THOMAS H. MEANS.

INTRODUCTION.

The southern part of the Territory of Arizona is made up of flat valleys or plains from which mountains rise abruptly in isolated peaks or short ranges. The uniform grade of the country, the warm and arid climate, and the presence of water in the large streams combine to make it an ideal land for irrigation. It has evidently been so considered for ages, for over the surface of the desert throughout the southwest are found relics of ancient peoples, their houses in ruins, their irrigation systems scarcely traceable, but nevertheless still numerous evidences of their existence. Evidences exist that this country was at one time thickly inhabited by an industrious people, but when first entered by white men only a few scattered Indian tribes were found along the permanent water courses. Though lacking in numbers, these were industrious, farming Indians, whose small canals and ditches covered the lands adjacent to the rivers. Since the advent of the white man with his new ideas the farming lands have been greatly extended, until at present in the Salt River Valley alone there are nearly 300,000 acres of arable lands lying below irrigation canals, of which probably one-third, or about 120,000 acres, are under permanent cultivation.

The importance of this southwest desert country as a farming and fruit district has long been recognized, but the development has largely been within fifteen years, and at no time has the progress been so rapid or substantial as at present.

The desert country at the present time is assuming a great importance in irrigation development, and to these perfectly graded lands a great extension of irrigated areas is looked for in the future. The one obstacle in the way of development is the scarcity of water at some seasons of the year. This obstacle is not insurmountable, for large quantities of water are lost every year in the heavy floods which sweep across the plains and down the valleys. The storage of this wasted water in the mountains by the construction of dams would enable a much larger area to be brought under irrigation.

This soil survey was conducted by the Division of Soils in cooperation with the Arizona experiment station. Prof. Robert H. Forbes, director of that station, suggested the areas to be surveyed, and assisted the field operations in many ways. Mr. J. Garnett Holmes,

in the employ of the Arizona experiment station, acted as field assistant throughout the work. The position of the area surveyed is shown in fig. 27, and in greater detail in fig. 28. A number of analyses and much information of value concerning the district surveyed were obtained from Professor Forbes.

FIG. 27.—Sketch map of Arizona, showing area surveyed.

GEOLOGY AND TOPOGRAPHY.

The material on the present surface of the southwest desert is the result of ages of erosion from the surrounding mountains, together with quantities of materials brought down from distant points by the streams.

The rocks which predominate in the mountains are granites and

more recent volcanic rocks, usually basalts. The surface material is almost entirely derived from these.

The Salt River Valley was once much deeper than at present. The waste which fills the valley was washed down from the mountain sides and canyons, gradually filling the older valley, uniting the smaller lateral valleys, and covering the hills in the bottoms until one great series of gently sloping plains was formed with only the tops of the mountains left showing above their own disintegration products. The depth of the washed material varies greatly with the locality, but when near the center of the valley, at Phoenix, a boring was made to a depth of 500 feet without striking rock, while recently a depth of 1,305 feet was reached at Mesa, the work ending in clay.

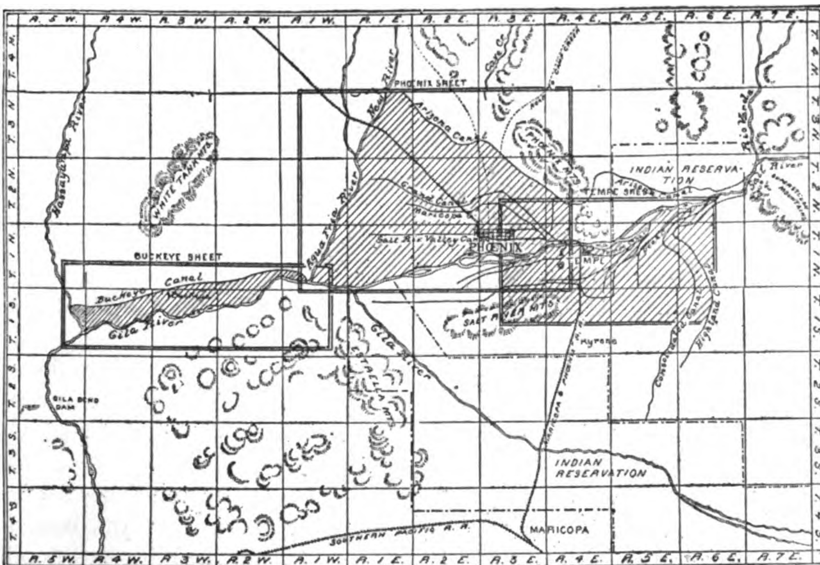


FIG. 28.—Sketch map of Salt River Valley, showing areas surveyed.

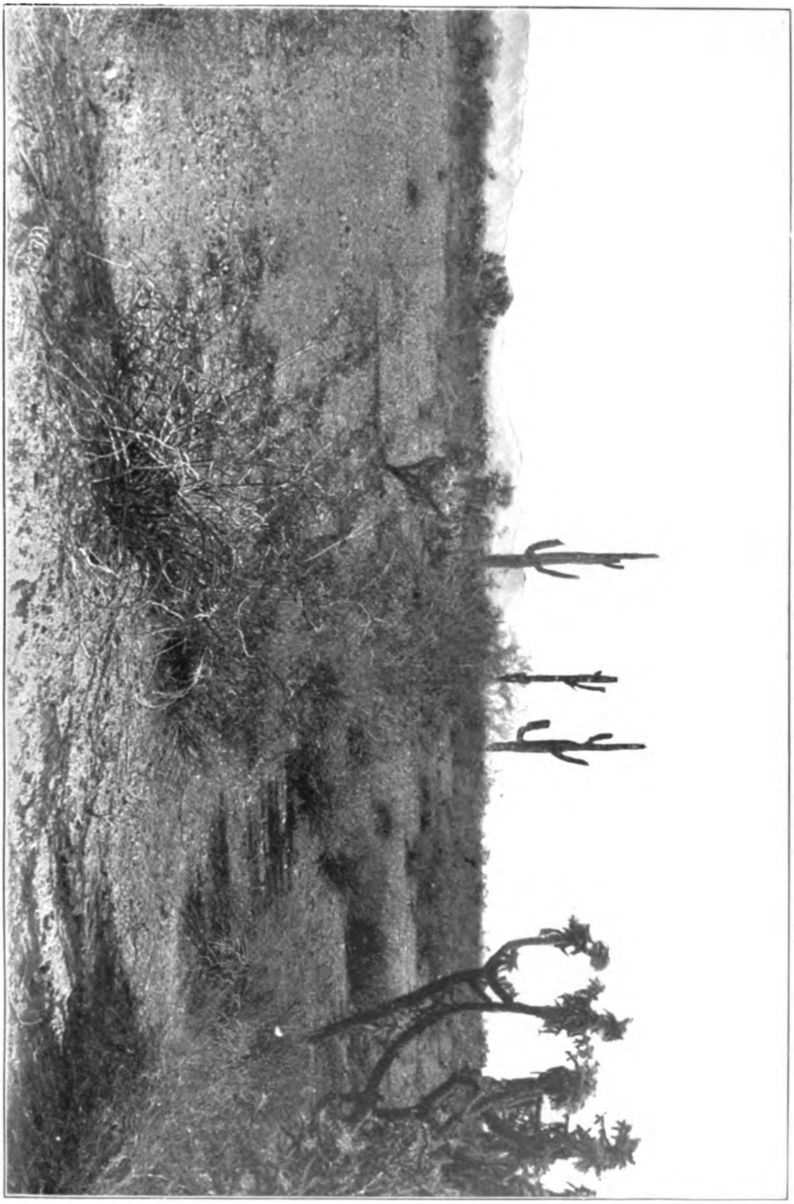
The formation of the Salt River Valley is naturally divided into two periods: A destructive cutting period, when the streams are constantly carrying material out of the valley, cutting it deeper and wider and tending to reduce the surface to sea level; and a constructive or filling period, when for any reason the stream loses its carrying power and the material from the higher levels accumulates in the valley, filling it up more or less in layers or strata.

Without going into details, the history of the valley has probably been as follows: The elevation of the southern part of the Territory gave the streams greater fall and thus increased their cutting power. Deep, narrow gorges were cut, slowly widening as the streams meandered and cut down the banks. The products of this erosion were car-

ried out and away into the ocean, leaving the surface of the land carved into deep valleys and high mountains. A gradual subsidence then began, the carrying power of the stream was reduced, and the débris brought down from the mountain sides and carried into the valley from the more elevated portions of the drainage basin was deposited, slowly filling the valley to near its present condition. This filling process is still going on. The fragments of the sides of the mountains are still being washed into the valley and the tendency is to bring the hilltops and the valleys to the same level. The greater part of the rainfall in this portion of the southwest comes in the form of heavy torrents, producing rapid rise in the streams and great carrying power for a short time. Thus, each canyon or arroyo entering the main valley deposits great cones of gravel and sand around its mouth, where the waters spread into a fan and lose their carrying power. Gradually these cones of débris spread until their bases meet and join, building the sediments higher at each flood. The washes from the mountain sides themselves spread sediments out and over the valleys. In this way the valleys are filled, the surface veneering material, except that which lies directly in the path of the present active washes, being carried but short distances from the nearest mountains, and should be classed as colluvial rather than alluvial. This porous material allows most of the water of ordinary times to sink and flow under ground, and it is only in times of heavy flood that the streams now carry water above ground.

The movements of the waste by flood waters only and the tendency of water to level everything in its way have been the causes of the nearly level land of the bottoms of the valley. This apparent level condition extends to the base of the mountains, the rise being gradual until the base of the mountains is reached, at which point the valley's surface abruptly ends and the steep slope of the mountains begins. The uniform slope of the lower levels is maintained by the floods which, rushing down the mountain sides, sweep in a thin sheet across the plain. Naturally the material in the center of the valley would be the finest, since it has been carried further.

Thus, it is true that the soils of the mountain slopes are gravelly and sandy, shading by almost imperceptible degrees down into heavier and clayey soils of the center of the valley. This arrangement of soils can be accepted as generally true of these valleys, except where other factors have entered to modify the texture or sequence of the soils. In the Salt River Valley there are three factors which have entered to modify the normal colluvial sequence. These are the flooding of the center of the valley by the Salt River and the consequent deposition of sediment or removal of materials already there; the action of the wind in accumulating fine sediments, such as dune sands; and the effect of irrigation with muddy water upon the soils.



CHARACTER OF NATIVE VEGETATION ON DESERT LAND NEAR THE MOUNTAINS. GRAVELLY SOILS. TEMPE AREA.

This last factor produces partly the effect of flooding by the river, but it is a factor entirely within the control of man. The change in texture due to the deposition of sediment is very noticeable in some of the lower soils, as will be shown later.

The origin of the normal soils of the valley is to be considered colluvial rather than alluvial, since the material is but the talus slope of the foot of the mountains spread out until nearly level. The wind-blown materials and the soils of the immediate river sides are of different origin, the one æolian and the other alluvial.

CLIMATE.

The climate of southern Arizona is distinctly arid, the temperature high and relative humidity low, but the wind movement slight, so that the evaporation is not so great as would be supposed from the relative humidity and temperature. The following figures indicate the mean monthly and annual temperature at several points in the Salt River Valley taken from data published by the Weather Bureau:

Mean monthly and annual temperatures.

Month.	Buckeye.	Experiment farm.	Mesa.	Phoenix.
	Deg.	*Deg.*	*Deg.*	*Deg.*
January	53.2	47.8	48.2	49.0
February	56.7	52.9	50.6	53.9
March	59.3	60.3	57.5	61.0
April	66.7	69.2	65.8	67.2
May	74.0	72.2	68.1	74.6
June	80.0	85.2	82.4	82.7
July	87.7	93.2	88.8	89.5
August	87.8	87.0	84.3	88.0
September	81.2	84.0	82.6	80.8
October	69.6	66.9	66.6	69.3
November	58.7	58.1	58.3	57.6
December	52.9	50.1	51.6	53.0
Year	69.0	68.9	67.1	68.9

The maximum temperatures range from 110° to 115° and occasionally higher, and the minimum temperature goes as low as 25°. Even with the high temperature which prevails during the summer the low relative humidity renders the sensible temperature much less.

The rainfall is distributed largely in two rainy seasons, July and August, and December and January. The following table shows the

normal monthly rainfall for six stations in the valley, compiled from all the data available from Weather Bureau reports:

Mean monthly and yearly precipitation.

Month.	Buckeye.	Experiment farm.	Maricopa.	Mesa.	Peoria.	Phoenix.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
January	1.08	1.20	.44	1.26	1.29	.57
February	.28	.11	.46	.34	.87	.89
March	.60	Tr.	.69	Tr.	.64	.68
April	Tr.	.00	.14	Tr.	.09	.30
May	.09	.00	.07	.00	.18	.16
June	.01	1.10	.06	.68	.01	.07
July	1.04	1.24	.40	1.65	1.08	.85
August	1.11	1.53	.91	.30	1.19	.97
September	.35	.89	.47	.76	.50	.54
October	.63	.34	.34	.31	.92	.62
November	.42	.48	.35	.46	.40	.44
December	.99	.12	.84	.06	1.16	1.12
Year	6.60	7.01	5.17	5.52	8.41	7.21

Elevation plays a great part in the rainfall, and since the irrigation water comes from the mountains, a consideration of the rainfall of the mountains is important. The rainfall and elevation are given for a number of stations within the drainage area of the Gila River.

Annual precipitation and elevation.

Locality.	Elevation.	Precipitation.	Locality.	Elevation.	Precipitation.
	Feet.	*Inches.*		*Feet.*	*Inches.*
Buckeye	900	6.60	Pantano	3,536	12.29
Phoenix	1,108	7.21	Oro	3,610	13.79
Experiment farm	1,110	7.01	Oracle	4,500	17.21
Maricopa	1,173	5.17	Dragoon	4,614	13.52
Peoria	1,200	8.41	Fort Grant	4,916	16.85
Mesa	1,244	5.52	Natural Bridge	4,990	18.70
Dudleyville	2,360	12.79	Huachuca Mountains	5,000	18.39
Tucson	2,430	12.11	Fort Apache	5,200	21.04
San Carlos	2,456	13.03			

An examination of these figures shows that for every 1,000 feet in elevation the rainfall increases 5.8 inches, or for every 260 feet in elevation the rainfall increases 1 inch. A large part of the watershed of the Gila River is above 5,000 feet and receives from 18 to 20 inches rainfall. This high rainfall, which largely comes in torrents, is the source of the heavy floods which pass down the Salt and Gila rivers.

The wind movement in the Salt River Valley is very slight, so slight that few windmills are in use. At higher elevations—Tucson, for example—the velocity is greater, but even then the windmills have to be adapted to light winds of 5 to 6 miles an hour.

At Phoenix the wind movement is shown by the following table, which is a summary of the Weather Bureau observations:

Wind movement, Phoenix, Ariz.

Month.	Daily.	Hourly.	Month.	Daily.	Hourly.
	Miles.	*Miles.*		*Miles.*	*Miles.*
January	54.0	2.2	August	55.0	2.3
February	68.0	2.8	September	41.9	1.7
March	57.1	2.4	October	44.9	1.9
April	75.3	3.1	November	46.6	1.9
May	62.2	2.6	December	45.6	1.9
June	64.3	2.7	Year	56.8	2.4
July	66.3	2.8			

With this light wind movement, even though the relative humidity is low and the temperature high, the resultant evaporation is much below that which the figures for the temperature alone would seem to indicate. Very little in the way of reliable or complete data can be found concerning the evaporation in southern Arizona. An estimate made from incomplete data by the U. S. Geological Survey gives the annual evaporation at Tempe as 91 inches. An average of three years observations made at Tucson by the Arizona experiment station gives 77.7 inches evaporation. This is the most complete record available and is perhaps more nearly correct than that published by this Survey. The general impression is that the evaporation in the Southwest desert is greater than in any other part of the United States. From all the data available, the western portion of Texas and eastern New Mexico from El Paso north has a greater yearly evaporation than any other part of the United States. This is largely due to the high average wind velocity and low humidity which prevail over this territory.

SOILS.

The soils have about the following areas:

Areas of the different soils.

Soil.	Tempe sheet.	Phoenix sheet.	Buckeye sheet.	Total.	Percentage of total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*	
Maricopa sandy loam	58,010	39,850	9,046	106,906	37.2
Glendale loess	....	52,040	....	52,040	18.1
Maricopa gravelly loam	17,680	32,720	666	51,066	17.8
Maricopa loam	10,420	10,230	....	20,650	7.2
Gila fine sandy loam	....	2,778	15,800	18,578	6.5
Pecos sand	5,652	6,600	1,708	13,960	4.8
Salt River adobe	6,084	7,571	....	13,655	4.7
Maricopa clay loam	4,699	4,014	....	8,713	3
Salt River gravel	1,804	....	....	1,804	.6
Total	104,349	155,803	27,220	287,372	....

PECOS SAND.

These sands are found along all rivers of the desert country and generally throughout the arid belt. They were first described in Report 64[1] of the Department as Pecos sands and that name has been retained. They are always close to the river and are sands brought down by the streams, washed out upon the neighboring lands at times of high water, and blown farther inland by winds in the form of low dunes. The characteristic vegetation of these sands and dunes is mesquite, willow, canaigre, cottonwood, and numbers of smaller plants. Great differences in the native vegetation exist because the depth to water, which is the most important controlling factor, varies greatly. Close to the river, where the water is near the surface, willows and cottonwoods predominate, while in the drier dunes mesquite is the most prominent plant.

The soil is usually deep, at least 6 feet of almost uniform sand, underlain at greater depths by gravel and bowlder beds through which the underflow of the rivers slowly moves. Along the margin of the areas, where the soils have drifted over other soil formations, the depth becomes less, gradually thinning out to a mere veneering of wind-blown or flood-drifted sand.

The texture of this character of soil is shown in the following table:

Mechanical analyses of Pecos sand.

No.	Locality.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4484	1¼ miles E. of Tempe	2.54	....	Tr.	4.20	30.07	33.39	21.70	7.48
4532	Mouth Hassayampa River	1.30	....	2.88	15.50	41.70	24.84	7.81	5.28

The first analysis, 4484, is typical of the Salt River sands, and 4532 is typical of the Hassayampa and Agua Fria rivers. The sands which are brought down by the Gila River are much finer than those carried by the other rivers. This is undoubtedly owing to the greater distance the sands are carried by the Gila River after leaving the

[1] Field Operations of Division of Soils, 1899, p. 62.

mountains. The following analysis shows the texture of the sands carried by the Gila River:

Mechanical analysis of sands carried by Gila River.

Land.	Diameter.	Per cent.
	Millimeters.	
Fine gravel	2 to 1	....
Coarse sand	1 to .5	....
Medium sand	.5 to .25	Tr.
Fine sand	.25 to .1	3.86
Very fine sand	.1 to .05	76.63
Silt	.05 to .005	14.34
Clay	.005 to .0001	1.73
Organic matter, loss	....	2.61

Such a soil, where mixed with a little more clay, is classed as a fine sandy loam, and in this way is formed the Gila fine sandy loam of the St. Johns and Buckeye districts.

These sand soils contain but small quantities of soluble matter throughout their extent. These salts are derived largely from the river waters, which always contain small quantities of soluble salts. The alkali salts are not present in sufficient quantity to be harmful to vegetation, and, moreover, the open texture of the soil permits the ready leaching of the salts by irrigation. Little of the river land is under cultivation. A small area south of Phoenix is largely devoted to truck crops and successful results there obtained recommend the soils for this class of farming. The soil is the natural home of canaigre, and if the cultivation of this plant will ever be a success it will be here. The soil is very light and leachy, and to improve its working and lasting qualities flooding with muddy water is to be recommended. The sediment of the river water at flood time is very rich in plant food, and its addition to the sandy soils will greatly improve them in many ways.

RIVER WASH.

This soil is the material occupying the bottoms of the many river and stream washes. The material is almost entirely gravel and sand mixed in a heterogeneous mass, and because of its position is never farmed. Of a similar class are the low islands in the stream channels.

SALT RIVER GRAVEL.

Lying along the edge of the mesa, north and west from Mesa, on the Tempe sheet, is a strip of very gravelly soil which has been named Salt River gravel. This soil is of little agricultural value, owing to the steepness of slope and amount of gravel. Parts of it, however, might make valuable land for the cultivation of grapes and olives.

GILA FINE SANDY LOAM.

As has been stated, this soil is sediment deposited directly from the Gila River. The same class of material was observed at the Maricopa and Phoenix Railroad bridge over the Gila River and from the mouth of the Salt River as far down the Gila River as the old Gila Bend dam, 33 miles below the Salt River.

The soil, like the Pecos sand, lies always close to the river, and as regards topography and native vegetation is similar to that soil. The mechanical composition of this soil is shown in the following table:

Mechanical analyses of Gila fine sandy loam.

No.	Locality.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4509	7 miles E. Buckeye	1.82	0.00	0.00	0.28	1.84	59.50	29.68	5.86
4530	1¼ miles E. mouth Hassayampa River	6.04		Tr.	1.04	2.86	37.45	42.14	10.05
4517	7¼ miles E. Buckeye	5.43			Tr.	2.56	49.26	32.21	10.33
4531	Arlington	5.56	Tr.	.90	1.42	2.60	39.02	36.96	12.17

The soil is almost entirely composed of very fine sand and silt with about 10 per cent of clay and small quantities of coarse sands. Such a composition produces a soil, very mellow, of easy working qualities, one which does not puddle easily or bake into hard clods. A soil of this type is adapted to a large variety of crops, and under irrigation would yield well with nearly any crops suitable to the climatic conditions. Such a soil under humid conditions would be classed as a corn loam and would correspond to the lighter bottom lands in the central Mississippi Valley. The soil closely resembles the lighter types of plains marl of western Kansas and Nebraska.

This soil invariably carries alkali salts in its uncultivated condition. Such is the natural result of its low position and great and rapid capillary power. The waters of the Gila River carry small quantities of alkali salts, and the evaporation from the surface of the soil has resulted in the accumulation of alkali. This soil, however, permits ready leaching, and wherever there has been good natural underdrainage little damage has resulted from the presence of the alkali salts.

SALT RIVER ADOBE.

There are several well-defined areas of heavy soil occupying positions near the trough of the valley. They show a section of 2 feet of heavy loam or clay, underlaid by sandy loam. They are generally

long, narrow strips, parallel to the river, with their lower margins covered with the Pecos sand. Above the long, narrow strips of adobe are found in many places evidences of ancient canals. These canals belong to the same prehistoric peoples as do the adobe ruins which are so abundant throughout the Southwest desert. From the number of the canals which have been found it is evident that the country was once much more thoroughly cultivated than at present, and that a great number of people were supported by the products of the irrigation. From the peculiar character of the soil and the position directly below ancient canals, it has seemed likely that it is the sediment from prehistoric irrigation.

The following table shows the mechanical analyses of the samples of adobe:

Mechanical analyses of Salt River adobe.

No	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4479	1 mile S., 7 miles W. Tempe.	0 to 21 inches	5.44	3.47	1.26	2.13	12.80	26.58	29.92	18.10
4449	2¼ miles S., 4 miles W. Phoenix.	0 to 12 inches	7.41	.14	3.46	3.58	6.70	21.38	34.74	21.87
4471	2 miles E. Tempe	0 to 24 inches	4.49	......	Tr.	3.26	7.66	23.38	27.05	33.24
4487	1¼ miles N. Mesa	do	7.00	......	Tr.	2.57	5.87	21.80	29.03	33.98
4435	2 miles S., 5 miles W. Phoenix.	0 to 12 inches	7.25	Tr.	.48	.49	2.37	22.37	32.52	35.05
4436	Subsoil of 4435	12 to 24 inches	7.82	Tr.	.28	.43	3.76	19.58	27.38	40.09

The subsoils of this adobe land are always a loam or sandy loam at a depth of 2 or 3 feet. The mechanical analyses of these subsoils are shown in the following table:

Salt River adobe subsoils.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4492	1¼ miles N. Mesa	24 to 48 inches	4.83	Tr.	1.27	1.85	13.16	41.05	23.84	14.96
4493	1 mile S., 7 miles W. Tempe.	21 to 48 inches	2.88	......	Tr.	1.73	17.52	37.85	24.21	16.25

In order to compare the texture of the adobe soil with that of the sediments which are at present being deposited by the river, the following mechanical analyses are given:

Mechanical analyses of sediment from Gila River.

No.	Locality.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4828	3 miles SW. Buckeye	6.86	Tr.	0.72	0.91	3.86	33.04	45.26	9.73
4534	Subsoil of 4828	9.11	....	.88	2.02	4.22	3.18	54.08	25.72
4525	7 miles S. Arlington	8.83	....	Tr.	3.16	9.10	7.76	40.70	30.24
4524	Subsoil of 4524	8.74	....	Tr.	2.14	3.10	3.75	44.40	38.41

Sample 4828 was collected at the upper end of a field which had a steep slope, and therefore this represents the coarser particles of the sediment. Sample 4534 was collected on the same farm, but represents the entire sediment of a flood. Samples 4525 and 4524 were collected from the bottom of the old Gila Bend Dam, and probably represent the sediment from a number of floods. A comparison of the mechanical analyses of these last three samples with the mechanical analyses of the adobe soil shows a great similarity. Moreover, from the appearance in the field, the color, general physical properties, action toward water, and their position with reference to the streams, these soils are undoubtedly sediments from the river waters. And since they are always found directly below the remains of prehistoric canals there seems to be no question but that the soils represent the sediment from prehistoric irrigation with muddy water. Samples of water have been collected from the canal 8 miles from the river which contained 6 per cent of sediment by volume. If 4 inches of such water were used every year, which would mean one good irrigation with the muddy water, one hundred years would be required to deposit 24 inches of this sediment. The amount of sediment now being deposited by irrigation waters often exceeds the amounts stated. Under the Buckeye Canal, which receives its water supply from the Gila River below the junction with the Salt and Agua Fria rivers, on an alfalfa field irrigated throughout the year, an average depth of 12 inches of sediment was found, the result of twelve years' irrigation. The waters of the Gila River below the Salt and Agua Fria rivers contain on an average more mud than do the waters of Salt River, so that this same depth of sediment is not found under the Salt River canals. It is possible that the ancient peoples, whose lands these adobes represent, raised but one crop each year and did not irrigate

the year through, in which case the yearly deposition of sediment would be smaller than the amount observed at Buckeye.

The soil as found at present is heavy, sticky, dark in color, contains more organic matter than do the other soils of the valley, and is richer in plant food. The great obstacles in the way of the practical management of this soil are the difficulty of working it when wet and the quantities of alkali salts which it sometimes contains. Water leaches through the soil very slowly; hence the removal of the alkali salts by underdrainage is a slow process. The subsoil of sandy loam will in a great degree assist in this underdrainage. For grain crops and alfalfa this soil is excellent. It is not so well adapted to fruit growing.

GLENDALE LOESS.

This soil covers a large area directly northwest of Phoenix, running in a northeasterly and southwesterly direction from the point where Cave Creek leaves the foothills nearly to the junction of the Salt, Gila, and Agua Fria rivers.

The great similarity of this soil to the typical loess deposits of the Mississippi Valley at once set it apart as differing in origin from the rest of the soils of the valley, and made the supposition likely that the material was similar to true loess in manner of origin. In the field a typical sample has the texture of a true loess, but is found to be interstratified with sands and gravels, though in no case is the material itself stratified, but presents the peculiar perpendicular bluffs characteristic of true loess. At first in the field work the soil was considered at least partly æolian; but a careful study of the conditions necessary for the wind deposition revealed no reason why an æolian soil should be deposited in this place and not in similar localities in the valley; moreover, samples of wind-blown material collected did not show the texture of the Glendale loess. The area extends in an irregular oblong from the point where Cave Creek issues from the foothills, directly down the maximum slope of the valley to the lowest point, the junction of the Gila and Agua Fria rivers. The stream bed of Cave Creek, which in its lower courses is entirely a flood stream, disappears just north of the Arizona Canal, and through the entire area the loess is locally known as Cave Creek wash. There are no surface indications of the wash. Old settlers in the valley were questioned as to the course of the waters of Cave Creek, and they said that the creek at times of high water flows southwesterly nearly down the center of the loess area as mapped, dropping off the low bluff just above the St. Johns Canal and flowing into the Gila River a hundred yards above the mouth of the Agua Fria. An examination was made of the portion of the area above the Arizona Canal, and it was found to narrow down, bordering the creek

in the form of a fan, with the creek as an axis. Part of the creek bed was formed of the same material.

The area of soil has the form of a low ridge, with the highest point about the center of the area, and with a uniform slope to the southwest. The minor undulations are slight, the soil being evenly graded and presenting surfaces capable of easy irrigation.

The texture of the soil is shown in the following table:

Mechanical analyses of Glendale loess.

No.	Locali	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4440	7 miles N., 3 miles W., Phoenix.	0 to 24 inches	3.78	Tr.	1.12	2.26	7.50	19.28	51.98	13.66
4429	1 mile E. Glendale	0 to 36 inches.	4.02	Tr.	.61	1.58	7.55	31.79	37.96	15.54
4430	Subsoil of 4429	36 to 72 inches	4.47	Tr.	.66	1.70	7.50	33.88	39.53	11.47
4436	7 miles N. Phoenix	0 to 12 inches.	4.12	1.67	1.90	3.21	7.18	25.75	35.94	19.39
4434	4 miles W. Alhambra	0 to 24 inches.	5.40	.49	.55	1.50	5.43	18.50	44.63	24.21
4432	7 miles N., 3 miles W., Phoenix.	do	3.09	.68	1.04	1.70	5.68	20.04	42.11	24.83
4439	Subsoil of 4432	24 to 48 inches	3.56	Tr.	1.96	2.44	7.60	33.54	38.34	12.63
4453	2 miles N. Phoenix	0 to 12 inches.	5.16	......	Tr.	.35	2.00	25.05	40.41	26.85
4431	2½ miles NW. Phoenix	0 to 24 inches.	8.13	Tr.	.85	.88	1.22	9.04	42.84	37.67

By this table it will be seen that the most important characteristic of Glendale loess is the presence of about 40 per cent of silt and 25 per cent of very fine sand. The clay varies greatly, and by its variation produces the light and heavy phases of the soil. Samples 4440, 4429, and 4436 represent the rather light phase of the soil, and at the same time that phase which works easier and produces the best results for the work spent in cultivation. Samples 4432, 4434, and 4453 represent a rather heavy phase of the soil. This phase of the loess is heavy for irrigation. The soil has a faculty of puddling; water does not enter readily, but flows over the surface and away in the waste waters. Extreme cases of this phase are designated "slickens" by the farmers. Sample 4431 is from the Arizona experiment station, 2½ miles northwest of Phoenix, and represents the heaviest phase of the Cave Creek material. The soil is dense, takes water slowly, bakes very hard after irrigation, and cracks in drying. Roots have difficulty in making their way through it after it has remained for a few years without cultivation, so that alfalfa dies out. The soil gives best results in crops which can be frequently cultivated.

The soil is generally uniform to a depth of 6 feet, though occasionally thin layers of more sandy material enter. Deeper, the loess becomes very sandy at times, and there are beds of gravel included.

As far as exposed through well borings the material is loess to a depth of 100 feet near the center of the formation around Glendale. Along the borders of the formation the material is thinner and is interstratified with the adjacent colluvial formation.

Professor Forbes, director of the Arizona experiment station, has published the chemical analyses of four typical soils from the loess area. The results of his analyses are embodied in the following table:

Chemical analyses of Glendale loess.

[By R. H. Forbes, Arizona experiment station Bul. No. 28.]

Constituent.	Forbes No. 3, sec. 32, T. 3 N., R. 2 E.	Forbes No. 5, sec. 7, T. 2 N., R. 2 E.	Forbes No. 7, sec. 5, T. 1 N., R. 2 E.	Forbes No. 8, sec. 6, T. 1 N., R. 2 E.	Average of four soils.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Insol	52.26	54.90	55.52	49.71	53.60
Sol. SiO_2	18.88	18.69	18.46	21.07	19.77
Al_2O_3	8.89	8.28	8.05	9.18	8.59
Fe_2O_3	6.45	6.15	6.22	6.04	6.21
CaO	2.21	2.72	2.70	2.42	2.51
K_2O	.96	.78	.82	.97	.88
Na_2O	.60	.47	.34	.45	.46
MgO	2.54	2.44	2.33	2.54	2.46
Mn_3O_4	.05	.05	.04	.04	.04
P_2O_5	.24	.22	.21	.21	.22
SO_3	.05	.05	.05	.08	.06
CO_2	.44	1.00	.89	.92	.81
Cl	.09	.04	.01	.01	.04
N	.04	.04	.06	.12	.06
Humus	.68	.57	.91	1.68	.96

These analyses show the soil to be in a highly decomposed condition, as only 54 per cent of the soil is insoluble in hydrochloric acid. The soluble portion carries rather large quantities of lime, potash, and phosphoric acid. The nitrogen content is low, but, according to the analyses of the irrigation water by Professor Forbes, the amount of nitrogen supplied in the water makes up the amount required by crops. It is interesting to note that the composition of these four soils is practically the same. This indicates a great uniformity of the soil, as has been found in the field examination.

The loess is generally free from alkali salts in large or harmful quantities. There are no areas of alkali salts in the main body of the loess. Small patches sometimes occur, but these are not often more than 10 feet across and are usually found along the lower edge of the field upon slightly raised portions which the water has not covered in flooding. Along the south edge of the area of loess a great deal of alkali is found thoroughly mixed with the soil and extending to a great depth. This salt is no doubt due to the washing and leaching action of the occasional floods down Cave Creek. These torrential floods would tend to carry the salts toward the lower border of the

formation and then gradually carry them out into the country drainage. Such is found to be the case. Along the south edge of the formation the water is nearer the surface, the soil is often submerged, and the alkali salts have accumulated from long periods of evaporation.

The loess soil of the Salt River Valley is, all things considered, the most desirable for general farming. The soil is not so well adapted to fruit growing generally, but is well adapted to grain and the growing of grapes. The condition, particularly of the heavy phases, can be improved largely by the incorporation of organic matter. Its general ease of tillage will thus be improved.

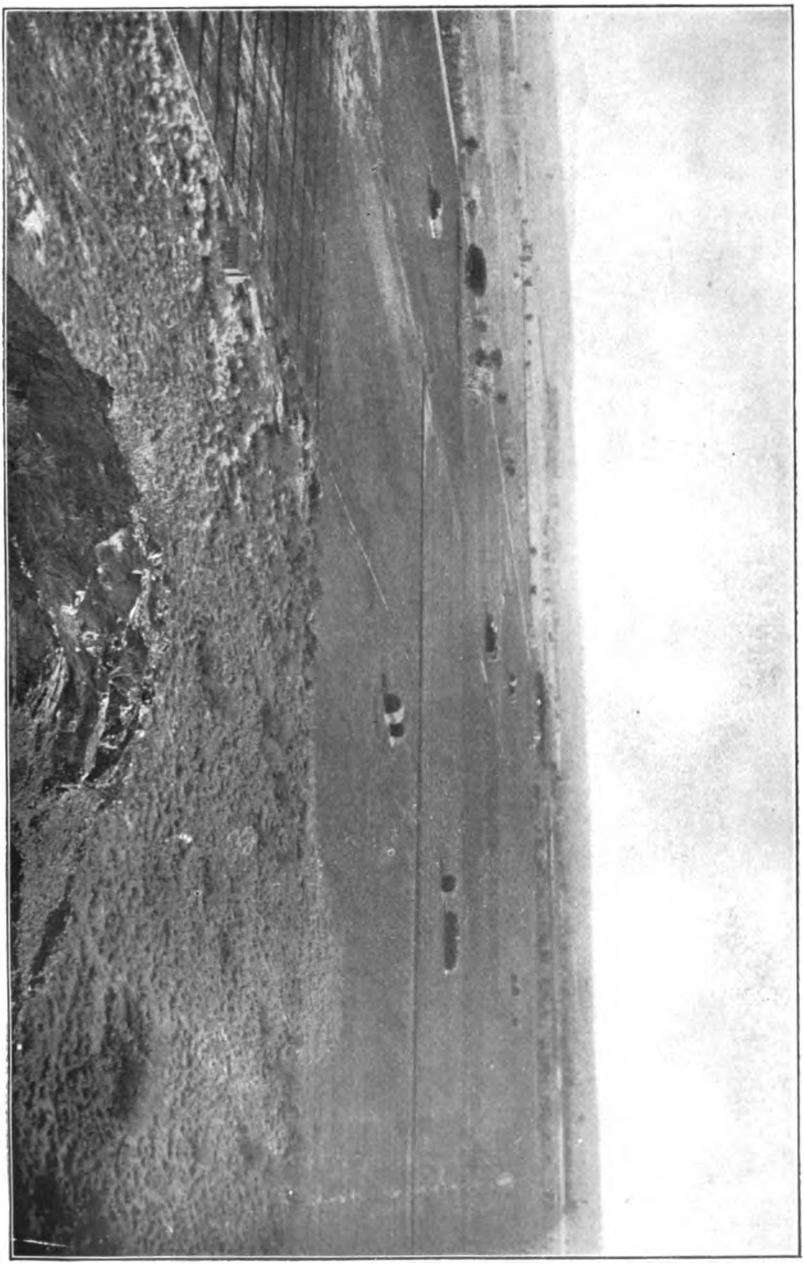
COLLUVIAL SOILS, OR MOUNTAIN WASTE.

Under the head of colluvial soils are included all the normal products of floods from the mountains immediately around the valley. It is true that in part the soils may be derived from the sediments brought into the valley from distant points by the streams, but the surface material of the valley is so largely derived from the waste of the sides of the mountains immediately surrounding the valleys, brought down by floods, that they may be considered colluvial soils. These colluvial materials, which are so largely granite, have been divided into four soils, depending upon the degree of communition of the rock. The Maricopa gravelly loam, the first product, is predominantly gravelly, with an average of 20 per cent of gravel coarser than 2 millimeters. The Maricopa sandy loam, though composed of the same original material, carries only 10 per cent gravel, while the Maricopa loam carries very small quantities of gravel. The Maricopa heavy loam is the heaviest soil from the colluvial material and is confined to small areas near the center of the valley.

MARICOPA GRAVELLY LOAM.

The Maricopa gravelly loam is the first of the colluvial products from the mountain sides. The soil is a rather light sandy loam, carrying from 10 to 25 per cent of gravel larger than 2 millimeters. The gravel and stones vary in size up to 10 centimeters ($2\frac{1}{2}$ inches) and are largely granite débris.

The soil lies along the lower mountain slopes and extends out upon the more level floor of the valley at varying distances, depending upon the proximity of large washes or mouths of extensive canyons. As a rule, the gravelly material extends about 2 miles from the base of the mountains. Beyond this limit the soils gradually carry less gravel and assume the character of the Maricopa sandy loam.



IRRIGATED LANDS IN TEMPE AREA.

Alkali spots showing on left.

The mechanical composition of the fine material is shown in the following table:

Mechanical analyses of Maricopa gravelly loam.

[Fine earth.]

No.	Locality.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4433	7 miles N. Phoenix	1.84	7.45	6.71	8.05	14.41	43.96	12.55	4.52
4445	One-half mile E. Peoria	1.70	11.10	10.84	11.84	14.76	28.00	16.27	5.59
4499	4 miles S., 1 mile W. Tempe.	2.00	8.18	7.96	8.64	14.74	31.40	19.85	6.28
	Average	1.85	8.91	8.50	9.51	14.64	34.45	16.22	5.46

This type of soil is generally deep, more than 6 feet, though in the lower part of a 6-foot section it may contain more gravel than it does at the surface, and may contain layers of a calcareous hardpan, locally known as "caliche." This hardpan never approaches the surface of the ground in the gravelly loam areas, except in the sides of cuts and washes.

The chemical character of this type of soil is well illustrated in the analyses which follow:

Chemical analyses of Maricopa gravelly loam.

[By R. H. Forbes, Arizona experiment station Bul. No. 28.]

Constituent.	Forbes No. 11, sec. 28, T. 1 N., R. 4 E.	Forbes No. 17, sec. 33, T. 1 N., R. 4 E.	Forbes No. 14, sec. 30, T. 2 N., R. 4 E.	Forbes No. 2, sec. 30, T. 3 N., R. 2 E.	Forbes No. 15, sec. 6, T. 1 N., R. 4 E.	Forbes No. 13, sec. 33, T. 2 N., R. 4 E.	Average of 6 analyses.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Insoluble	71.98	74.29	75.02	73.65	71.66	67.47	72.35
Soluble SiO_2	10.31	9.80	9.58	9.82	9.52	12.51	10.29
Al_2O_3	5.14	5.06	4.76	4.84	4.21	5.62	4.94
Fe_2O_3	4.21	3.98	4.67	5.07	4.02	4.52	4.41
CaO	2.07	1.34	1.35	1.28	3.51	2.85	2.07
K_2O	.67	.78	.59	.56	.68	.69	.66
Na_2O	.23	.21	.25	.27	.26	.46	.28
MgO	1.39	1.32	1.19	1.36	1.47	1.45	1.36
Mn_3O_4	.03	.06	.07	.04	.09	.02	.05
P_2O_5	.06	.08	.06	.12	.15	.05	.09
SO_3	.02	.05	.03	.03	.03	.05	.03
CO_2	.85	.52	.21	.21	2.05	1.40	.87
Cl	.01	.01	.01	.01	.01	.15	.03
N	.03	.04	.03	.05	.04	.03	.04
Humus	.29	.56	.45	.40	.93	.41	.51

These analyses show a relatively large amount of insoluble matter for an arid soil. This would indicate the incomplete decomposition of the materials from which the soil is derived. The lime and potash content is high, phosphoric acid content is good, but the content of nitrogen low. There is very little humus, which accounts for the low nitrogen content.

The soil, occupying, as it does, the lower slopes of the mountains, is often well protected from frost, and is in excellent position for the cultivation of citrus fruits. Along the base of Camelback Mountain, northeast from Phoenix and extending westward close to the base of the Phoenix Mountains, is an area of this soil which is being rapidly planted with citrus fruits. Fruit trees in general do well on a light soil of this type and their cultivation can be recommended. The incorporation of mud or silt from the irrigation waters and the addition of organic matter through green manures will greatly improve the physical and chemical properties of this soil. Alkali does not occur in the Maricopa gravelly loam in sufficient quantity to damage crops.

MARICOPA SANDY LOAM.

The Maricopa sandy loam is the second of the colluvial soils from the granite mountains. It is to be regarded as the gravelly loam, more finely powdered. The soils have small quantities of gravel, generally less than 10 per cent. They occupy the higher levels of the plain portions of the valleys, and in point of area are the most important soils of the valley.

The mechanical analyses of this soil follows:

Mechanical analyses of Maricopa sandy loam.

[Fine earth.]

No.	Locality.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4506	5½ miles SW. Buckeye	2.80	4.04	5.70	7.07	16.46	43.30	13.16	6.57
4489	3 miles S. 6 miles W. Tempe	3.14	6.20	6.08	6.51	12.99	39.40	17.68	7.26
4519	4 miles W. Buckeye	3.86	10.19	15.76	18.89	15.78	18.38	6.78	10.45
4494	4 miles S. Mesa	2.96	Tr.	2.37	14.48	26.85	27.12	12.95	12.50
4483	2 miles S. 3 miles E. Tempe	3.20	Tr.	5.72	8.06	15.46	32.40	20.47	13.80
4491	7 miles S. Tempe	3.27	Tr.	1.43	2.22	9.28	34.30	32.78	15.99
4490	2 miles S. 2 miles W. Tempe	4.40	2.81	6.50	7.21	11.71	32.68	17.09	17.85
4470	1 mile N. Mesa	7.29	......	Tr.	1.89	9.24	30.25	23.65	18.68

These mechanical analyses show the soil to carry on an average about 13 per cent of clay, or over twice as much as the gravelly loam,

though the soils range in clay content from 6 per cent to nearly 20 per cent. This is to be expected, since these soils are all derived from one source, and are not laid down in distinct strata.

The finer grinding of the material has resulted in the more complete decomposition of the granite. This makes soluble in hydrochloric acid more of the material, and a chemical analysis shows more plant food in the soluble portion. The soil can not be said, from the analyses above, to carry more plant food, but more of the insoluble plant foods are rendered soluble in acid by the more thorough decomposition. The following analyses illustrate this fact.

Chemical analyses of Maricopa sandy loam.

[By R. H. Forbes, Arizona experiment station Bul. No. 28.]

Constituent.	Forbes No. 4, sec. 32, T. 3 N., R 2 E.	Forbes No. 6, sec. 7, T. 2 N., R. 2 E.	Forbes No. 10, sec. 5, T. 2 N., R. 3 E.	Forbes No. 1, sec. 30, T. 3 N., R. 2 E.	Forbes No. 9, sec. 7, T. 2 N., R. 3 E.	Forbes No. 18, sec. 30, T. 1 N., R. 4 E.	Forbes No. 12, sec. 28, T. 2 N., R. 4 E.	Average of 7 analyses.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Insoluble	65.75	67.27	68.87	63.53	65.20	61.57	66.06	65.47
Soluble SiO_2	12.56	11.88	10.86	15.69	14.69	15.77	11.29	13.25
Al_2O_3	5.61	5.43	5.70	7.74	7.10	6.79	5.52	6.27
Fe_2O_3	5.82	5.35	5.17	4.92	4.06	4.50	4.05	4.92
CaO	3.03	2.88	2.45	.98	1.28	2.61	4.21	2.49
K_2O	.53	.47	.63	1.03	.86	1.05	.78	.76
Na_2O	.36	.41	.28	.33	.30	.31	.27	.32
MgO	1.99	2.03	1.67	1.76	1.71	2.01	1.56	1.82
Mn_3O_4	.06	.09	.05	.08	.10	.05	.04	.07
P_2O_5	.15	.14	.11	.05	.11	.15	.05	.11
SO_3	.05	.05	.04	.04	.05	.08	.04	.05
CO_2	1.30	1.28	1.16	.00	.23	1.38	2.57	1.13
Cl	.02	.02	.01	.01	.01	.03	.01	.01
N	.03	.03	.04	.04	.04	.06	.06	.04
Humus	.30	.71	.61	.71	.68	.81	.66	.64

Here it is seen that the sandy loam contains only 65 per cent insoluble matter, while the Maricopa gravelly loam carried 72 per cent insoluble matter. This 7 per cent of matter, which has been rendered soluble in hydrochloric acid by the more complete decomposition of the granite, is uniformly distributed among the soluble constituents. Thus, a comparison of the tables shows that the lime, potash, and phosphoric acid content of the soluble portion is greater; or, in other words, there are probably more of these constituents available for the use of plant roots. The nitrogen content is not increased, although there is a slight increase in the humus. The soil is really deficient in these two constituents, and the incorporation of more nitrogen-bearing organic matter will improve, both in tilth and in composition. The crops grown on this soil are varied. Fruit crops do well, and alfalfa does well wherever the "caliche" or hardpan is not dense enough to prevent the penetration of the roots.

MARICOPA LOAM.

By more complete weathering and by the washing of the finer products of weathering from the Maricopa gravelly loam and sandy loam there has accumulated in the lower parts of the valley a soil similar in origin to the gravelly and sandy loams, but much heavier. This soil, the third product of the colluvial washings, is called the Maricopa loam. The areas occupied by it lie in the lower portions of the valley, immediately north of Phoenix and in the low area south of Tempe. The soils were naturally flooded in time of heavy rain and their texture has probably been changed by the large amounts of water thus soaking through them.

The mechanical analyses show the soil to be much heavier than the sandy loam.

Mechanical analyses of Maricopa loam.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
4486	8 miles S. Tempe, Ariz.	0 to 36 inches	4.69	1.28	3.85	9.34	18.17	21.97	18.46	21.79
4485	Subsoil of 4486	36 to 72 inches	2.43	3.09	3.64	10.34	18.84	19.97	26.30	14.99
4478	3 miles E., 4 miles S., Tempe, Ariz.	0 to 36 inches	7.19	......	Tr.	1.93	6.10	19.07	38.43	26.74
4481	Subsoil of 4478	36 to 60 inches	5.68	Tr.	1.51	3.12	12.80	22.17	29.17	25.73
4480	1 mile E., 6 miles S., Tempe, Ariz.	0 to 36 inches	5.40	1.88	1.51	2.66	7.94	25.62	21.98	33.41
4488	Subsoil of 4480	36 to 72 inches	4.38	Tr.	1.70	1.92	12.40	30.24	24.13	24.86

The soil in its normal phase carries from 20 to 25 per cent of clay, but in extreme cases runs up to nearly 30 per cent.

No chemical analyses of this type of soil are available; but from the analyses which have been given and those which follow the average composition can be inferred. The finer grinding and more complete weathering of the granitic material will render more of the resulting soil soluble in hydrochloric acid, and thus there will be apparently more plant food shown in an agricultural analysis.

The crops grown on this soil are generally alfalfa and grains. The low position and compact nature of the Maricopa loam do not make it a good fruit soil, so that its area is largely given over to general farming.

The low position and compact nature are both favorable for the accumulation of alkali salts; and in the field the soils are found to be frequently spotted with alkali, and in a large district south from

Tempe the soils are in many cases so alkaline as to be worthless for general farming. These areas, however, can be profitably reclaimed, as will be shown later.

MARICOPA CLAY LOAM.

The extreme type of the colluvial washings, which is confined to rather small areas, has been designated the Maricopa clay loam. This soil, which is simply heavier than the Maricopa loam, has otherwise the same properties. The clay content is almost 30 per cent on an average, though some samples show scarcely more clay than does the average loam, the apparent difference being in the arrangement of the clay grains, which gives the soil a heavier appearance in the field.

The following chemical analysis by Professor Forbes is the only analysis of this soil available for publication.

Analysis of Maricopa heavy loam.

[By R. H. Forbes, Arizona experiment station Bul. No. 28.]

Constituent.	Forbes, No. 19, sec. 34, T. 1 N., R. 5 E.	Constituent.	Forbes No. 19, sec. 34, T. 1 N., R. 5 E.
	Per cent.		*Per cent.*
Insoluble	54.90	Mn_3O_4	0.05
Sol. SiO_2	19.59	P_2O_5	.23
Al_2O_3	9.62	SO_3	.05
Fe_2O_3	5.23	CO_2	.33
CaO	1.24	Cl	.01
K_2O	1.96	N	.04
Na_2O	.45	Humus	.83
MgO	2.10		

Even though but one analysis is available, which of course is not as decisive as the average of six or seven analyses, such as are quoted under the Maricopa gravelly loam and the Maricopa sandy loam, yet an examination of this one analysis shows that the principles which were found to hold in those analyses are carried out in this one, that is, that the soil is more thoroughly weathered, and therefore more soluble in hydrochloric acid, and the analysis shows more plant food. The lime in this one analysis is lower than the lime of the other analyses, but this is very likely due to the fact that the lime may have been leached out. The soil is rich in potash and phosphoric acids, but, as in the other analyses, nitrogen and humus are low.

Perhaps the greatest difficulty in the way of managing these soils is the dense structure, due to the large quantity of clay present. Water flows very slowly through them, and plant roots have some difficulty in penetrating it. Organic matter and thorough tillage will aid greatly in their improvement.

HARDPAN.

Underlying nearly all of the soils of the valley, more particularly the colluvial soils, is found a white, calcareous hardpan, locally known as "caliche." This hardpan is not in continuous layers, and from its disconnected character the roots of most plants are able to penetrate it. Moreover, since lime is the cementing material. water gradually softens it and permits the roots to penetrate.

This hardpan has been formed by the washing down of the lime from the upper layers of the soil and the accumulation of this material at the maximum distance reached by the water. Thus, as the soils have been built up, different layers of hardpan have been formed, so that at present the hardpan material often is found through great depths. The gravel in the deeper portions of the valley is often cemented by this calcareous material.

SOIL MAPS.

The areas surveyed have been shown on three separate sheets accompanying this report. The soils of the three sheets have all been correlated and in the descriptions of the soils which have just been given the entire area surveyed in the Salt River Valley has been considered together. For the better understanding of the maps they will now be considered separately.

TEMPE SHEET.

The Tempe sheet occupies a position on the south side of the Salt River, as shown in fig. 28, and all of the irrigation water is taken from that river. The area extends as far east as the Highland Canal and includes in that direction all of the land irrigated. The southern limit of the map is the central line of Township No. 1, south. Irrigation canals have been built much farther south than this. The Consolidated Canal has been extended as far south as the reservation line, 9 miles south of the limit of the map. In fact, the area between the Salt and Gila rivers is nearly all susceptible of irrigation. The map, however, includes about all of the area which has been irrigated, the present supply of water being inadequate for the irrigation of the complete area under ditch.

The Salt River enters the area covered by the sheet at the northeast corner, traversing it in an irregular line and passing off the sheet about the middle of the west side. The eastern part of the sheet is on the lower slopes of the wash from the Superstition Mountains, the maximum slope following a line nearly parallel with the Salt River and about 4 miles south of that stream. At a point immediately south from Tempe the ground begins to rise toward the west to the Salt River Mountains, which occupy the southwest corner of the sheet. North of this line of maximum slope the land also slopes

toward the Salt River and south of it slopes toward the Gila River. Thus, the area is seen to be a saddle with the lowest point about 4 miles south from Tempe. The only other topographic feature of note is the bluff bordering the mesa land around Mesa. The trend of this bluff is shown by the area of gravelly land, the Salt River gravel. At a point directly west from Mesa the bluff breaks down, and beyond that point southward the change in elevation is scarcely noticeable. The bluff north of Mesa, about its maximum point, is 40 feet high. The soils of the mesa are uniformly a sandy loam, with the exception of two areas of clay loam immediately south of Mesa. Below the mesa, along the river, the sandy loam predominates, with the sandy soils along the river and patches of adobe showing in low spots of the sandy loam. In the low part of the saddle immediately south from Tempe the loam is the chief soil, flanked by sandy loam, excepting along the northern border, where an adobe has been interposed over the loam in part. West of Tempe is another area of adobe overlying sandy loams.

PHOENIX SHEET.

The Phœnix sheet covers the land north of the Salt River, east of the Agua Fria and New rivers and south of the Arizona Canal, the eastern boundary being drawn at the Crosscut Canal. The entire area is one unbroken, evenly sloping plane, with a nearly uniform slope toward the southwest. A slight ridge or divide follows the trend of Cave Creek. This divide is occupied by the Cave Creek loess soil, which is bounded on the north by sandy loam, grading into gravelly loam near Agua Fria and New rivers. To the eastward of the loess the gravelly loam, immediately under the Arizona Canal, grades into sandy loam and the loam around Phoenix, and in these soils are spots of clay loam. Immediately in Phoenix and extending in a long finger southwest from the town is a large area of adobe soil. The land adjacent to the Salt River is all sandy, and below the junction with the Gila the Gila fine sandy loam occupies an area below the St. Johns Canal.

BUCKEYE SHEET.

The Buckeye sheet covers the area below the Buckeye Canal, extending from the mouth of the Agua Fria along the Gila to the Hassayampa River. The area immediately along the river is all Gila fine sandy loam, except a small area of sand soil along the Hassayampa. Back of the fine sandy loam is the Maricopa sandy loam with a few small intrusions of gravelly loam from the slopes of the Whitetank Mountains. The area is narrow; the slope from the canal to the river is great. Along the boundary between the fine sandy loam and the sandy loam a shallow draw extends from the canal to

Gila River, just south of Buckeye. This draw probably represents an old bed of the Agua Fria River.

IRRIGATION WATERS.

The irrigation water which is used upon the area covered by the three sheets is all taken from the Salt and Gila rivers. With the exception of the Buckeye Canal, which waters the land shown on the Buckeye sheet and which is taken from the Gila River below the junction with the Salt River, all of the water is taken from the Salt River. The largest and most important canals are taken out of the Salt River between McDowells Butte and a point on the river north of Mesa. The Arizona Canal takes water from the north side of the river and conveys it to a point about 7 miles northeast of Phoenix and there drops part of the water by way of the Crosscut Canal to the Grand, Maricopa, and Salt River Valley canals, all three of which originally diverted water directly from the river just below Tempe. On the south side of the river the Consolidated Canal diverts water from the river which is distributed to several smaller canals just northeast of Mesa. The Highland Canal, which heads in the river above the Consolidated Canal, receives water only at times of flood, and for that reason is practically unused. Below the Consolidated, the Utah and Tempe canals take water directly from the river.

The water of the river, which sinks into its porous bed below McDowells Butte, is forced to the surface by the bed rock north of Tempe Butte, so that at Tempe there is always water in the river. At Tempe the second series of canals is taken out. This water is taken out on both sides of the river. On the south side of Salt River two small ditches, the Broadway and the Mavmonier, take water from the river. On the north side the Salt River Canal drains the river in times of low water and this water is mixed with that received from the Crosscut Canal.

Below the mouth of the Agua Fria the Buckeye Canal takes water from the Gila River. These two canals have a permanent supply of seepage water, for the flow of the Salt and Gila rivers at these points is largely seepage and has never been known to fail. The character of the water in these canals varies greatly with the season of the year, as flood waters vary greatly in composition, depending upon the portion of the watershed from which the flood comes, and they in turn also differ from the normal flow of the river.

The Arizona experiment station, under the direction of Prof. Robert H. Forbes, has studied the condition of the waters. Professor Forbes has placed his data at the disposal of the Division of Soils. The table which follows is compiled by him from the station records:

Composition of the waters of Salt River.

Constituent.	Salt River irrigation waters, representing the original supply, taken at the Consolidated Canal office, Mesa, Ariz.							
	Low summer water. Average of 4 weekly composites of samples taken daily, Aug. 1-Sept. 1, 1899.	Summer flood water. One weekly composite of daily samples taken Sept. 1-Sept. 9, 1899.	Low summer water. Average of 4 weekly composites of daily samples taken Sept. 9-Oct. 9, 1899.	Winter flood water. One composite of daily samples taken Oct. 9-Oct. 17, 1899.	Low winter water. Average of 10 weekly composites of daily samples taken Oct. 17-Dec. 30, 1899.	Low winter water. Average of 13 weekly composites of daily samples taken Feb. 17-May 30, 1900.	Very low summer water. Average of 8 weekly composites of daily samples taken June 1-Aug. 4, 1900.	Buckeye Canal seepage water, J. R. Day's ranch. Summer seepage water. Average of 6 weekly composites of daily samples taken May 10-June 21, 1900.
Per cent of silt:								
By volume	0.78	2.35	0.36	1.59	0.15	0.12	0.11	0.056
By weight	.32	.95	.096	.714	.025	.024	.026	.004
Partial analysis of solubles (parts in 100,000):								
Total soluble solids (110° C.)	72.40	110.00	114.20	95.20	102.64	106.90	139.15	197.23
Chlorine as NaCl	46.2	52.1	72.9	61.9	67.6	72.2	98.1	130.2
Alkalinity as Na_2CO_3, Heburr's process	....	1.80	....	....	....	....	....	....
Permanent hardness as $CaSO_4$, Hehners's process	(?)1.38	....	2.79	2.45	2.12	5.43	18.70	33.27
Nitrogen (parts per 1,000,000):								
Total nitrogen in silt and water	6.94	26.7	4.36	12.19	1.96	1.48	1.30	1.10
Nitrogen in nitrates	1.32	1.2	1.90	1.52	1.21	.67	.78	.85
Nitrogen in nitrites. Traces nearly always.								
Analytical figures calculated to probable compounds (parts in 100,000):								
Silica, SiO_2	1.33	....	....	....	....	....	....	....
Alumina and iron oxide	....	....	....	....	....	....	....	....
Sodium silicate, Na_2SiO_3	3.31	1.79	9.35	....	7.46	8.50	5.69	8.70
Sodium chloride, NaCl	27.84	42.80	60.84	....	67.54	72.16	96.04	116.90
Sodium sulphate, Na_2SO_4	....	....	....	....	4.97	3.46	.07	....
Sodium carbonate, Na_2CO_3	....	1.80	....	....	....	....	....	....
Potassium chloride, KCl	2.45	2.69	2.07	....	....	....	....	2.15
Potassium sulphate, K_2SO_4	....	....	....	....	3.40	2.74	2.50	....
Magnesium chloride, $MgCl_2$	6.88	5.81	8.34	....	....	....	....	9.34
Magnesium sulphate, $MgSO_4$	....	4.32	3.39	....	....	....	....	....
Magnesium carbonate, $MgCO_3$	....	....	....	....	9.93	10.21	11.49	11.76
Calcium chloride, $CaCl_2$	7.50	....	....	....	....	....	....	....
Calcium sulphate, $CaSO_4$	13.87	1.92	6.46	....	3.18	5.87	11.00	20.84
Calcium carbonate, $CaCO_3$	....	24.09	13.36	....	7.71	7.00	8.20	17.87
Total net compounds	63.18	85.22	103.81	....	104.19	109.44	136.99	186.56
Less CO_2 by calculations	....	11.35	5.88	....	8.59	8.44	9.64	13.83
Net	....	73.87	97.93	....	95.60	101.00	127.35	172.73

This table shows the chemical character of the water of the Salt River for a year and of the Buckeye Canal for over a month during the summer, at which time the water is perhaps the most concentrated. If all of these salts remained in the upper foot of the soil upon the evaporation of the water, the soils under the upper Salt River canals would be too alkaline for alfalfa in a few years; the Buckeye soils would be in the same condition, but in a shorter time.

It is not probable that this salt all remains in the top foot, nor is it likely that all of it remains in the soil at all. There is often suffi-

cient percolation to remove quantities of the salt, and it is fortunate that in the Buckeye country where the water is the most plentiful the ground is porous and the supply of water so generous as to admit of occasional heavy flooding.

Soils have been irrigated with the Buckeye water for eleven years, and there has been no accumulation of alkali salts where the drainage has been good. The fact that the flood waters are purer offers a ready means of leaching the salts which may accumulate. The simple use of the irrigation waters in the Salt River Valley can not be regarded as dangerous. The amounts of alkali salts held in the water are not sufficient to collect in harmful quantities, but if this water be allowed to subirrigate the land the accumulation of the alkali salts is rapid. Certain areas of land in the valley have been subject to subirrigation and upon them the accumulation of alkali is often great enough to prevent useful growth. Such areas are found in the country south of Tempe and along the Salt and Gila rivers below Phoenix, but wherever the drainage is good the land has never been damaged by the use of the water.

The sediment which is carried by the water in flood time is very important on account of its fertilizing value and also on account of the effect this sediment has in changing the physical properties of the soil to which it is applied. The amount of this sediment which is present in the water was mentioned in the discussion of the Salt River adobe. Forbes[1] has published an analysis of an adobe soil, but as this soil has been subject to subirrigation for a long time and has become badly charged with alkali salts the analysis can not be considered typical. The analyses of two samples of sediment, made by F. P. Veitch in the Division of Soils, gave the following results:

CaO.	P_2O_5.	K_2O.
3.34	Trace.	.86
3.71	Trace.	.63

So far as these analyses were carried, the sediment is seen to be fairly rich, except in phosphates. The nitrogen added in the sediment is perhaps more important than the other plant foods. In the water analyses by Forbes, quoted above, the nitrogen in the silt is shown.

UNDERGROUND WATERS.

Water is found everywhere in the gravels beneath the valley, the depth and amount of matter in solution varying greatly. The level

[1] Arizona experiment station Bulletin No. 28, p. 87.

of standing water and its character have no doubt been much changed during the years in which irrigation has been practiced. Little is known of the condition existing before irrigation, except that the water was deeper than now. The sketch map on page 289 shows the river systems of the valley. All the streams are dry most of the year, except in places where the bed rock is near the surface of the ground. For example, the Salt River at McDowells Butte and for 5 or 6 miles below always contains water, but immediately northwest from Mesa the stream bed is dry during part of the year. At Tempe the water again rises, and for a mile the river is above ground. South of Phoenix the stream bed is generally dry, but about 8 miles southwest of Phoenix the water again rises, and from that point the Salt and Gila rivers are above ground for 50 miles or more. The constant flow of the streams when above ground clearly shows that there is a constant flow under the ground through the gravels and sands. Moreover, the increase in underflow indicates that a portion of the water which is applied by irrigation returns to the streams from which it is taken. The irrigation of the great plain around Phoenix will undoubtedly increase the flow of the Salt and Gila rivers near the initial amount. Such an increase has already taken place, but exactly how much can not be said. Continued irrigation should increase the flow even more, and when all the land below the Arizona Canal is irrigated the flow will be greater than it is now. The subflow is perhaps the most permanent source of irrigation water in the valley. The gravels and sands of the valley act as a storage reservoir, and the resistance to the flow of water through this material acts as a regulator upon the flow. No records of the Gila River at the head of the Buckeye Canal have been kept, but it is doubtful if the amount of true seepage water varies 10 per cent during the year. A similar state of affairs is found in the Los Angeles River in southern California. Here records of the flow have been kept, and though the last five years have been unusually dry for southern California, the flow of the Los Angeles River has been almost constant.

One great objection to the use of seepage water is the amount of alkali salts often contained in it. In the case of the Buckeye Canal it has been seen that the water is contaminated with a rather large quantity of salts, but the drainage of the soils is naturally so good as to prevent the accumulation of these salts. The depth to standing water and the character of the underground water is a matter of such importance in discussing the soils of the valley, particularly in regard to the accumulation and character of the alkali salts, that a study of the well waters was undertaken. It is to be regretted that a greater amount of time was not available for the extension of the study of the underground waters over a greater area, for the movements of the waters directly under the areas surveyed is but a small part of the general movement.

TEMPE SHEET.

The sketch map (fig. 29) shows the depth to standing water in a general way. Over the area immediately south of Tempe and stretching indefinitely southward over the lower part of the saddle toward Gila River is an area of land in which the water stands less than 10 feet from the surface of the ground. The fluctuations of the level of the ground water are great. Over some of the land during wet seasons, when the rivers are high and irrigation water plentiful upon the mesa south of Mesa, the level of standing water comes very close to the surface, often less than 1 foot. At the time the survey was made the level was not closer than 6 feet at any place.

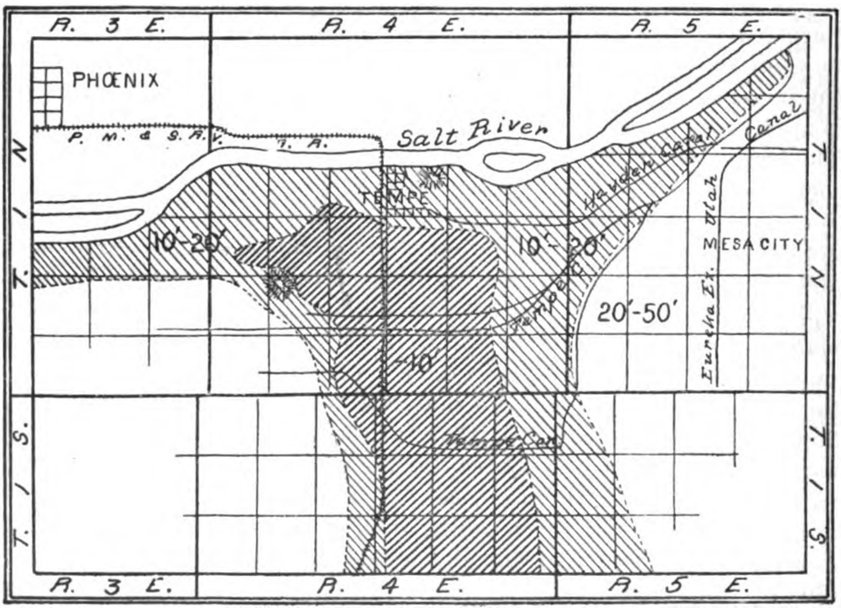


FIG. 29.—Depth to standing water, Tempe sheet—less than 10 feet, from 10 to 20 feet, and from 20 to 50 feet.

Professor Forbes[1] has published the analyses of a number of well waters, and the field party on this survey also examined a number of well waters. On an average the wells carry 200 parts solid matter in 100,000 parts of water. The analyses show about one-half of the salts to be sodium chloride. Sulphates are not a prominent feature of the salts. Sodium carbonate is found in most of the wells in the southern portion of the area. Small amounts of nitrates are general in all of the waters. When waters of this character approach the surface of the ground close enough to permit of a rapid upward capillary movement, the accumulation of alkali at the surface is rapid. Over the

[1]Arizona experiment station Bul. No. 30.

area where water is near the surface alkali salts are common, and over part of the area the accumulation has become sufficient to prevent useful growth.

Outside of this area of water within 10 feet of the surface are zones in which the water is lower down. The sketch map shows a zone in which water is 20 feet or less from the surface. This zone covers nearly all of the cultivated land which is not on the mesa. On the average these deeper waters do not vary much in composition or total solids from the more shallow waters. This is especially true of the wells within the irrigated areas not upon the mesa. The wells on the mesa are, as a rule, not so alkaline as the wells below the mesa.

PHOENIX SHEET.

The portion of the valley which is covered by the Phoenix sheet is a uniformly sloping plain, with a southwesterly dip, the lowest point being at the junction of the Salt, Gila, and Agua Fria rivers. Underlying this plain water is found everywhere at shallow depths near the lower edge of the plain, increasing in depth as the slope ascends in a northeasterly direction. North of Phoenix, around the foot of the Phoenix Mountains and the mouth of Cave Creek, the wells are more than 100 feet deep. The character of the water in these wells is usually good, generally less than 150 parts solid matter in 100,000 parts of water. Between this zone of deep water and the north boundary of Township 1, north, the wells vary from 20 to 100 feet in depth. The character of these waters varies greatly. There are different strata of gravel carrying waters of different composition, so that the depth of the well makes a difference in the salt content of the water. Generally speaking, the salt content is about 200 parts solid matter in 100,000 parts of water, though wells have been examined containing 350 parts solids. These salts are about one-half sodium chloride, with calcium and magnesium carbonates, and in some wells sodium carbonate. Sulphates are present in small quantities, and nitrates are present, but seldom amounting to more than 1 part in 100,000 parts.

The depth to standing water in the wells in township 1 north is shown in the sketch map (fig. 30). Three zones of depth to standing water are represented on this map by rulings. All of the area adjacent to the Salt River has water under it at a depth of 20 feet or less. The character of this water is not different from the water of the zones before described. In the lowest part of the plain, near the junction of the Agua Fria, water is less than 10 feet from the surface of the ground.

Over the area underlaid by these two zones of shallow water alkali salts are commonly found. The reason for the accumulation in these places is the same as that given for the accumulation on the Tempe sheet, that is, the presence of the water so near the surface of the

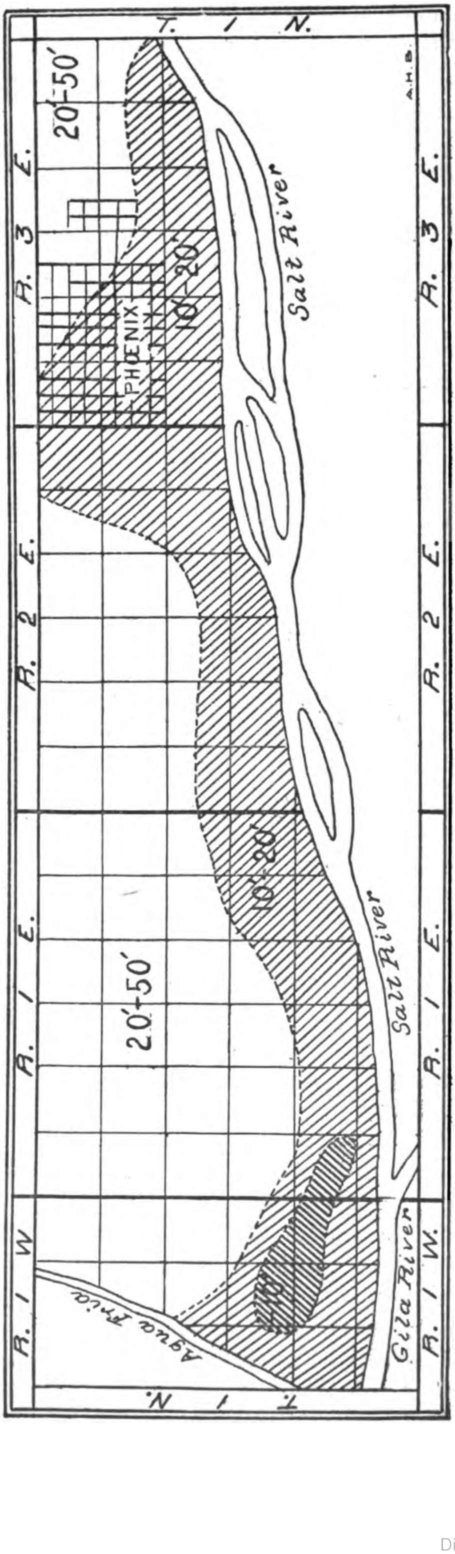


FIG. 30.—Depth to standing water, Phoenix sheet—less than 10 feet, from 10 to 20 feet, and from 20 to 50 feet.

ground as to permit rather rapid upward movements by capillary action. On the Phoenix sheet, however, the area in which alkali salts are in great quantity is relatively small, almost entirely confined to the area along the river southwest from Phoenix. Little has been done toward the reclamation of this land; some of it has been cleared of the saltbush. The area of maximum accumulation is under the St. Johns Canal, where the water is very near the surface. This water is the seepage from the great Glendale loess area, and the salts which have accumulated are from the washings of the salts of that area.

All of the wells close to the Agua Fria River contain water of very good quality. The underflow of the Agua Fria is known to be of good quality. The following analyses were furnished by Professor Forbes:

Richardson's Ditch water, sec. 15, T. 1 N., R. 1 W.

[In parts per 100,000.]

Constituent.	Feb. 24, 1900.	Apr. 23, 1900.	Constituent.	Feb. 24, 1900.	Apr. 23, 1900.
NaCl	6.00	7.4	SO_3	2.40	Strong.
Na_2CO_3 (Hehners)	1.17	1.27	N (nitrates)	.16	0.148
Hardness (Hehners)	0.00	0.00	N (nitrites)	.004	Trace.
CaO	7.00	Strong.	Total solids	30.0	33.4
MgO	2.52	Pronounced.			

This is the best water to be found in the Salt River Valley, so far as known. The wells close to the stream bed of the Agua Fria contain better water than the wells a few miles back, indicating that the water of the underflow spreads out and mixes with the waters of the adjacent soils. The amount of underflow is not thought to be large, for examinations of Gila River above and below the Agua Fria show no dilution due to inflow from this stream. Water developed along this stream is perhaps the best water in the valley for brewing purposes, beet-sugar manufactories, or other manufactories requiring a good supply of water.

BUCKEYE SHEET.

The depth to underground water on the Buckeye sheet is shown on the sketch map (fig. 31). Three zones of depth are there mapped. The shallowest zone, that in which water is 10 feet or less in depth, follows the draw which runs nearly parallel to Gila River. This draw is probably an old channel of the Agua Fria, and at present water from the Agua Fria underflow undoubtedly follows along under it. A line of wells of relatively good water is found along this line, and at the mouth of the draw just south of Buckeye a series of springs issue from a conglomerate or gravel bed. This water is much purer than either the canal water or the well waters outside of the draw,

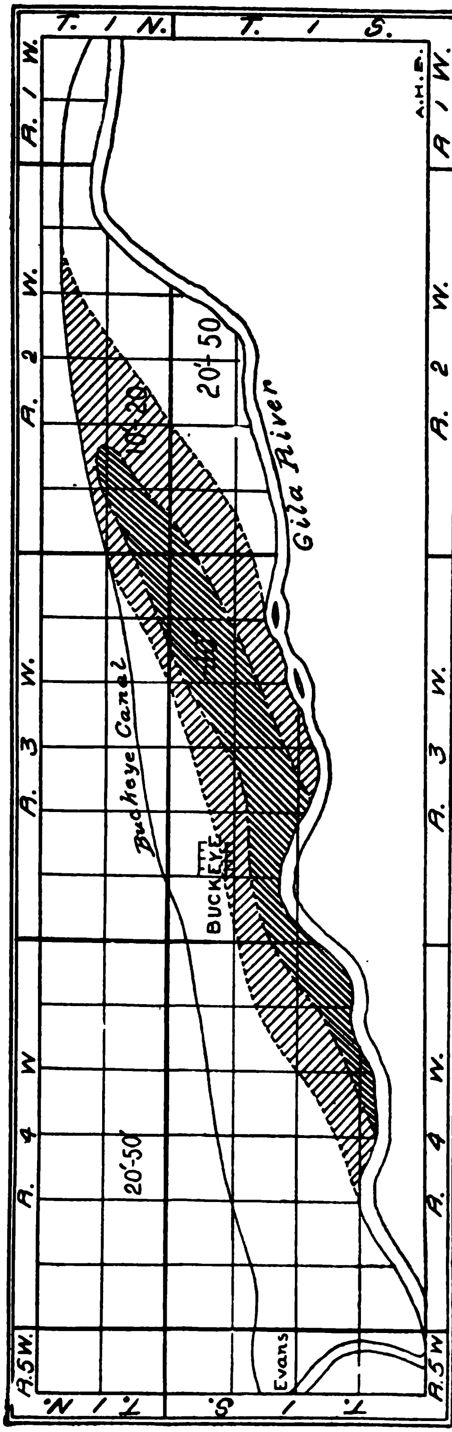


FIG. 31.—Depth to standing water, Buckeye sheet—less than 10 feet, from 10 to 20 feet, and from 20 to 50 feet.

and therefore could not have originated in one of these sources. As far as can be judged, the underflow from this draw is small. There is a dry channel running up to one of the largest canyons on the southeastern side of the Whitetank Mountains, and no doubt the underflow in part is due to floods from the canyon.

South of this draw, upon the upland along the south extension of the Buckeye Canal, the wells are deeper (20 feet or more) and the waters carry about 300 parts solid matter per 100,000 parts. This upland is a bar of Gila fine sandy loam, which separates the Gila River from the Buckeye draw. The capillary powers of this soil are very great, and the water which underlies the soil has risen to the surface and evaporated. Therefore the accumulation of alkali is general over much of the fine sandy loam.

North of the draw, west of the town of Buckeye, the waste from the Whitetank Mountains has washed down to the Gila River bank, and the wells underlying the slope are from 20 to 50 feet in depth. The water in these wells contains about 200 parts solids per 100,000 parts water. Along the Hassayampa bottoms the wells are 30 feet on the average. The underflow from the Hassayampa is supposed to be very small.

ALKALI OF THE SOILS.

The presence of alkali salts within the soils is a natural consequence of their formation in an arid region, and the phenomena here are not very different from those in other districts which have been described in these reports.

The rocks immediately around the valley are granite; yet the upper parts of the drainage basin are in sedimentary and volcanic rocks, and the characteristics of the alkali from the decomposition of the granite are in a measure modified by the products of decomposition of the other rocks. Since there are distinct features in each sheet, each area will be considered in detail.

TEMPE SHEET.

The chemical character of the alkali of the Tempe area is shown by the following analyses, made under the direction of Dr. Cameron, of the Division of Soils. The analyses are presented in ions, and for the convenience of those unaccustomed to this mode of presentation the ions are combined into salts in the usual conventional method. Acknowledgment must be made that nothing is known about the actual state of composition of these salts when in solution, since changes and interchanges between the various positive and negative ions are always going on and the proportions of the various salts may vary as the concentration of the solutions changes. Thus, while in the first sample all of the sulphates are calculated as calcium

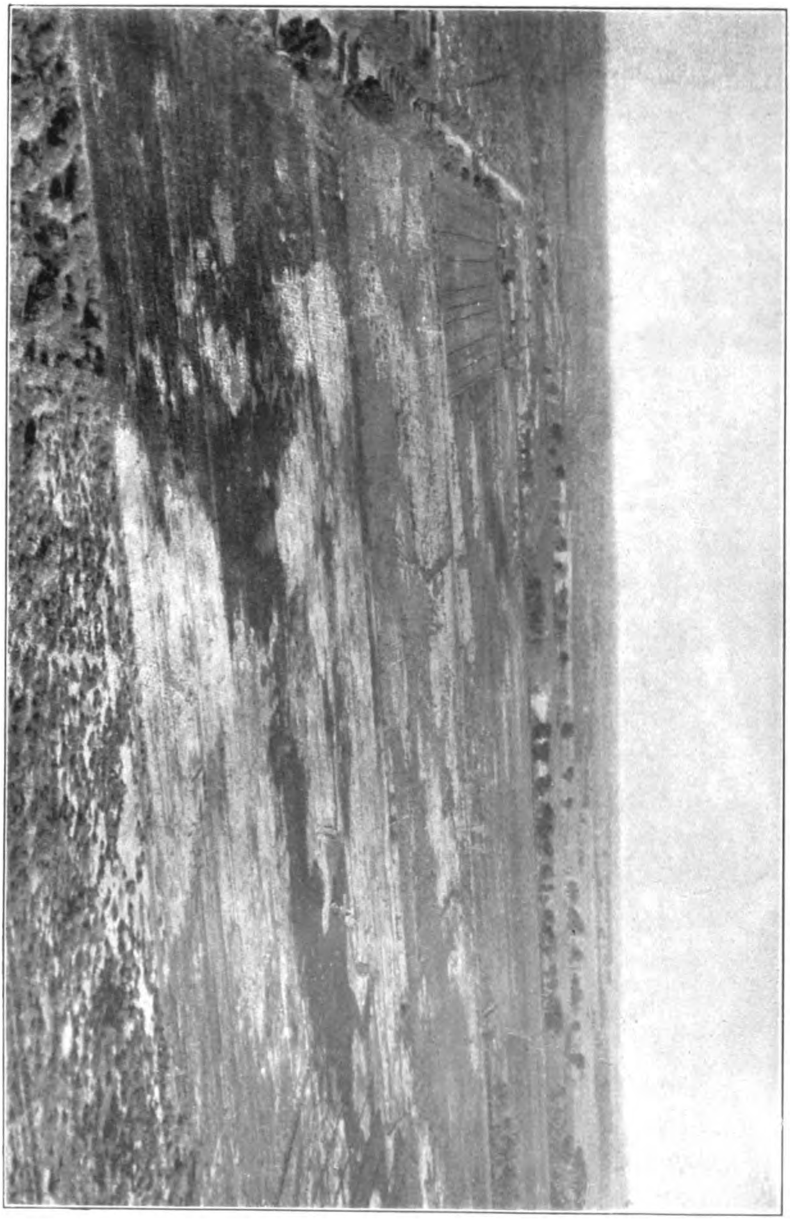
sulphate, it is known that there will be in the solution combinations of sulphuric acid with all of the bases present.

Chemical analyses of alkali salts of Tempe sheet.

Constituent.	4470. Sec. 9, T. 1 N., R. 3 E. (0–12 inches).	4469. Sec. 27, T. 1 N., R. 4 E. (0–12 inches).	4541. Sec. 22, T. 1 N., R. 3 E. (crust).	4468. Sec. 3, T. 1 S., R. 4 E. (crust).	4472. Sec. 3, T. 1 S., R. 4 E. (0–12 inches).	4465. Sec. 22, T. 1 S., R. 4 E. (crust).	4466. 2 miles S. Kyrene (crust).
Ca	13.32	0.31	6.87	0.47	0.65	6.78	4.88
Mg	4.44	.31	4.20	.62	.57	4.08	1.24
Na	14.93	34.90	23.08	30.99	31.55	22.04	29.47
K	2.88	2.50	0.00	6.40	5.01	2.12	1.65
SO_4	5.34	12.16	28.40	9.60	9.76	.91	16.78
Cl	56.93	46.38	39.55	42.01	41.73	61.48	44.83
CO_3	....	.18	.10	2.34	1.45	....	....
HCO_3	2.16	3.28	....	7.57	9.28	0.70	1.62
$CaSO_4$	7.56	1.07	22.31	1.56	2.18	1.28	14.86
$MgSO_4$	....	1.52	13.34	3.04	2.74	....	6.13
$MgCl_2$	17.40	....	5.94	....	....	15.81	....
KCl	5.46	4.74	0.00	12.18	9.53	4.03	3.18
NaCl	35.98	72.84	57.97	59.72	61.35	60.33	71.55
Na_2CO_3	....	.31	1.44	4.14	2.50	....	....
$NaHCO_3$	2.94	4.47	....	10.38	12.76	.96	2.27
Na_2SO_4	....	15.05	....	8.98	8.96	....	2.06
$CaCl_2$	30.66	....	....	....	....	17.59	....
Per cent soluble salts	3.33	4.47	7.24	2.56	2.48	8.58	5.80

Thus, it is better to consider the ions rather than the salts formed from them, as these later may and probably do change with the concentration and temperature of the liquid as well as with any change in the relative proportion of the ions. The relation between the carbonate and bicarbonate is particularly subject to change, and the analyses as given are not to be taken as the relation which would be found in the field. The drying of the sample, change of temperature, or even exposure to the air will greatly change the relations of these two salts, and the analyses simply indicate the amounts found in the sample when received in the laboratory.

Chlorine and sodium ions are the most prominent ions present and their composition as sodium chloride gives 60 per cent of this salt on an average. Intermixed with this chloride we find variable quantities of sulphates. Since all of the samples contain lime, this sulphate upon drying will react with the lime upon any soluble carbonates present and prevent the formation of sodium carbonate or black alkali. Thus, in most of the samples no sodium carbonate was found. In three samples small quantities of sodium carbonate were found in the crust, yet when this amount is figured on percentage of the soil, there is seldom more than 0.02 per cent, or an amount which is negligible. The Salt River water carries sulphates and lime in solution; hence there is little danger that black alkali salts in harmful amounts will result in soils irrigated by such water. In this connection it is



PATCHES OF ALKALI IN ALFALFA AND GRAINFIELD, TEMPE AREA.

Once very fertile.

interesting to note that south of the area surveyed, extending along the base of the Salt River Mountains to Gila River, is an area of alkali land which has never been watered by the river and which carries small quantities of black alkali.

The reactions between the various salts in the water and their action upon the solid particles within the soil have been considered by Cameron.[1] He has further shown [2] that in the reactions between the various solutes that all possible combinations of the ions form and accumulate in the soil or crust under certain conditions. The essential reacting salts in the Salt River Valley are sodium chloride and calcium carbonate. From their mutual reaction sodium carbonate and calcium chloride result and are always present in the soil. The river waters carry small quantities of sulphates which react with any sodium carbonate which may be present and prevent the accumulation of the black alkali. On the other hand, the small quantities of calcium chloride which form move very readily in a soil, and oftentimes accumulate in great quantities. The calcium chloride is in the crust as a deliquescent salt, and not in large or well-defined crystals, as are some of the other salts. Therefore, the water which falls upon the crust dissolves, first of all, calcium chloride, and carries it down into the soil. And, moreover, calcium chloride moves more rapidly within a soil than do the other chlorides.[3] For these reasons calcium chloride is carried down into the subsoil, and when this subsoil water again comes to the surface at another place lower down, the calcium chloride is deposited.

Origin of alkali salts of Tempe sheet.—The alkali map which is given in fig. 32 shows all of the areas of alkali lands in the Tempe area. Three subdivisions are made: Lands in which the alkali salts are less than 0.25 per cent, and in which for the present it may be neglected; lands with from 0.25 to 0.50 per cent of alkali, which are more or less dangerous for crops; and lands with more than 0.50 per cent of alkali, upon which most crops will not grow. All of the areas of alkali land are seen to lie in the lowest part of the saddle between Salt River Mountains and Superstition Mountains, with the exception of a few small areas on the mesa. The alkali lands lie on both sides of the divide between the Salt and Gila rivers.

It has been shown that the cause of the alkali in this lowland has been the rise of the underground water through irrigation on the uplands, and also that when the water on the upland is scant and there is little irrigation the level of water in the wells south of Tempe lowers from 6 to 10 feet. At such times of low water the alkali of the soils slowly disappears through irrigation and fields are reclaimed slowly.

[1] Report No. 64, Dept. Agr., p. 141.

[2] Cameron, Bulletin No. 17, Dept. Agr., Division of Soils.

[3] Means, Yearbook, Dept. Agr., 1898, p. 498.

Upon the rise of the subsoil waters, however, the alkali returns to the surface through evaporation. During the time the area was being studied the water was low and fields were in cultivation which two years ago would not permit seed to germinate. The farmers were of the opinion that conditions were becoming better all the time. The land south of Tempe shows plainly the value of intelligent and diligent farming. Side by side are seen farms, some of them in good condition and paying interest upon the work and money invested, and others are barren alkali wastes, blots upon the land and a menace to progress. Persistent and intelligent treatment of the alkali lands has

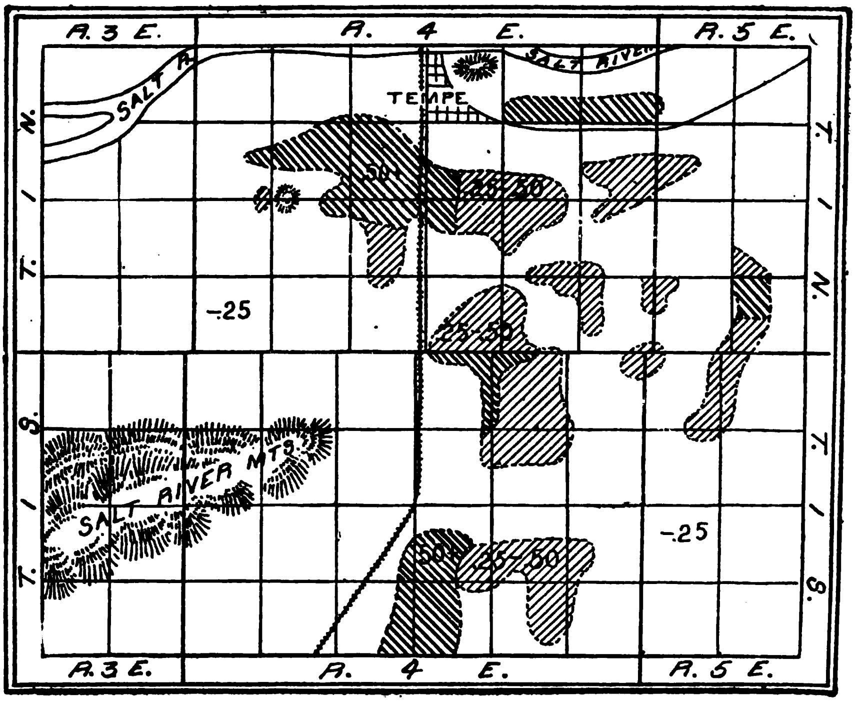


FIG. 32.—Alkali lands, Tempe sheet, showing lands with less than .25 per cent; lands from .25 to .50 per cent; and lands over .50 per cent to depth of 5 feet.

always resulted in victory for the farmer, while careless cultivation even of good land has been known to result in an alkali flat. The district south of Tempe was once called the "garden spot" of the Salt River Valley, and a great portion of the country is yet worthy of that designation.

The damage which has resulted from the alkali and seepage water was not inevitable. All or nearly all of it could have been prevented. The present condition of affairs comes from the tendency to look no deeper than the bottom of a furrow. Had the fact been known that everywhere underneath the surface of the ground was water charged with alkali, and this fact should have been known, since the well

waters carry sufficient alkali to taste, the rise of this water in the wells should have given warning that drainage was needed and that some assistance should be given to the natural drainage and that the level of standing water should be kept below the zone of roots and rapid capillary action. Such a note of warning was given and has been repeated with every rise in the wells. No heed has been paid to the matter, and with each rise in the water table the burden of alkali salts is increased.

If the water table were kept down for a period of years, or kept down indefinitely, rainfall would tend to bring matters to their virgin condition, and the alkali salts would be washed down below the zone of root action. This would be a very slow process, but the application of irrigation water, cultivation, and ordinary farming processes would greatly accelerate this removal of salts. Thus, it is believed possible to reclaim the entire area of alkali lands south of Tempe. The question then comes: How can the level of standing water be kept down? The natural underdrainage served to keep the water down as long as there was but the rainfall to carry away.

Reclamation of alkali lands.—So soon as the extra amount of water applied to the surface by irrigation begins to fill the soil, the standing water commences to rise. The only permanent remedy is to increase the drainage facilities through artificial drainage. In the absence of accurate surveys of the country, the best location of these drains can not be given. Two outlets are possible, and both must be used. One main ditch emptying into the Salt River and one emptying into the Gila River will be necessary. The ditch emptying into the Gila need not be dug all the way to the river, but the water can be carried on the surface of the ground part of the way. By opening in this way two outlets for the underground water to escape, it is deemed possible that any rise in the subsoil water as the result of irrigation can be prevented. The entire area of alkali land is underlaid by gravel, and the tapping of this gravel bed will drain the soil. It is not thought likely that tile drains under each field will be found necessary, but deep drains at intervals of every one-fourth or one-half mile should so keep down the soil water and so readily remove the seepage water from excessive irrigation that there can be no rise in subsoil water. With the subsoil water at a depth of 5 or 6 feet and an easy movement of water through the land, the reclamation of these alkali lands becomes a matter easily assured with intelligent management. Nor is it deemed necessary to invest large sums in the reclamation of the lands without any immediate returns. Very much of the land, even in its present condition, will grow some crop—sorghum, sugar beets, or Australian salt bushes—and these crops can be grown for two or three years without financial loss. Then, as the salts slowly leach away, barley and wheat can be introduced, and finally a good stand of alfalfa secured.

One method of management which is fruitful of results in the Salt

River Valley is the deep plowing of alkali lands. Often the bulk of alkali salts is immediately upon the surface of the ground, while the soil at a depth of 8 inches or a foot is comparatively free from salts. If this land is plowed deeply this crust of alkali is turned under and the good soil raised to the surface. Moreover, the soil is broken up and the irrigation water is given greater opportunity to dissolve the alkali salts and carry them down. Thus, in the good soil on top of the ground the seeds germinate and the plants are well established before the alkali has again reached the surface. Since a well-established plant is much less sensitive than a young seedling, in this way lands can be successfully planted in grain which would otherwise grow nothing. And again, since the alkali salts are brought to the surface entirely in the water which rises from the subsoil by capillary movement, and are left on the surface by the evaporation of this water, any way of lessening the amount of capillary water brought to the surface, or of lessening or preventing its evaporation, will tend to retard or prevent the accumulation of alkali at the surface.

Cultivation serves both purposes, that of breaking up the uniform capillary spaces and preventing the rise of the water, and in covering the ground with a layer of dry soil and preventing evaporation. The effect of frequent cultivation can not be given too much importance in the reclamation of alkali soils. Cases have been noted where cultivation has reduced the accumulation of alkali salts to one-third of the amount on uncultivated land. The effect of cultivation upon conserving the moisture of the soil is too well known to need the presentation of figures, and whenever water is prevented from evaporating there the accumulation of the alkali salts is prevented or retarded.

The incorporation of organic matter, such as coarse stable manure, leaves, the plowing under of a crop of weeds or green manure, in a measure tends to break up the capillary pores into larger spaces, and thus retards the upward movement of subsoil water. But much greater retardation results if this organic matter is spread over the ground in a uniform layer or mulch. Cases can be cited where this method alone has prevented damage by alkali to an orchard, while orchards all around not so treated have been injured.

If the soil be compact and slow to drain, or if the establishment of drains around the fields does not lower the water surface promptly to at least 3 feet, tile drains or more frequent open drains are necessary. Too much importance can not be attached to this point. Soils must be well drained and aerated before the maximum efficiency can be realized, and until soils are freed from standing water to a depth of at least 3 feet, there is little need to do anything else, for drainage is of prime importance.

For the reclamation of alkali lands in the Salt River Valley the following outlined method of treatment has been found efficient and profitable:

1. Insure good and rapid drainage to a depth of 3 or 4 feet.

2. Plow deep—12 inches.

3. Furrow land and plant sorghum in the bottoms of the furrows. Irrigate heavily and gradually cultivate down the ridges.

4. After two years in sorghum—deeply plowed each year and cultivated frequently—plant barley. Have the surface of the ground well leveled, and flood heavily before planting.

5. Seed to any desired crop, for if the land is at all porous a stand of any ordinary crop can be secured except on the worst spots.

6. Watch the ground closely, and if the alkali begins to return, or if the few spots remaining begin to enlarge rapidly, plow up and again put in some crop which can be cultivated.

There are many plants which can serve as well as sorghum; for example, sugar beets, asparagus, and onions stand large quantities of alkali. Among the fruits, the date palm, pomegranate, pear, and fig are arranged in order of the amount of alkali withstood. All can be said to be more resistant than peaches, apples, or citrus fruits. Date palms withstand large amounts of salts. In fact, there is little if any land in the Salt River Valley too alkaline for mature date palms.

PHOENIX SHEET.

Alkali salts of the Phoenix sheet are largely confined to a narrow area bordering the Salt and Gila rivers. The distribution of these alkaline lands is shown on the map (fig. 33). The chemical composition of a number of samples of the alkali is given as follows:

Chemical analyses of alkali salts of Phoenix sheet.

Constituent.	4421. Sec. 23, T. 2 N., R. 3 E. (0-1 inch).	4419. Sec. 23, T. 2 N., R. 3 E. (0-12 inches).	4416. Sec. 34, T. 2 N., R. 2 E. (0-1 inch).	4423. Sec. 35, T. 2 N., R. 2 E. (0-1 inch).	4417. Sec. 19, T. 1 N., R. 2 E. (hardpan).	4452. Sec. 12, T. 1 N., R. 3 E. (0-24 inches).	4418. Sec. 2, T. 1 N., R. 2 E. (0-12 inches).	4413. Sec. 20, T. 1 N., R. 1 E. (0-3 inches).	4447. Sec. 18, T. 1 N., R. 2 E. (0-12 inches).
Ca	15.36	6.66	15.92	1.33	....	13.18	11.48	8.57	9.50
Mg	4.88	....	2.02	2.56	....	4.31	.87	3.57	4.36
Na	14.33	15.52	10.28	32.64	38.58	10.89	24.67	22.40	18.84
K	....	17.34	5.88	....	....	7.16	....	2.50	4.45
SO_4	6.85	16.29	.85	9.80	2.23	2.29	2.76	1.29	2.97
Cl	58.61	33.42	40.86	53.67	5.90	50.14	54.88	60.78	58.86
CO_3	....	....	....	....	4.31	....	....	....	1.05
HCO_3	....	10.77	....	....	2.98	12.03	1.80	1.89	....
NO_3	Tr.	....	24.19	....	....	....	....	Tr.	....
$CaSO_4$	9.64	22.95	1.19	4.60	....	3.15	3.88	1.83	4.18
$CaCl_2$	34.93	....	43.29	....	....	33.81	28.75	22.21	22.83
$MgSO_4$	....	....	....	8.16	....	....	....	....	....
$MgCl_2$	18.67	....	7.75	3.56	....	16.62	3.35	13.99	17.08
KCl	....	32.72	....	....	....	13.47	....	4.76	8.45
Na_2SO_4	....	....	....	....	3.28	....	....	....	....
NaCl	36.76	29.58	12.16	83.68	85.06	16.62	61.55	55.99	45.64
$NaNO_3$	Tr.	....	20.53	....	....	....	....	....	....
Na_2CO_3	....	....	....	....	7.56	....	....	....	1.83
$NaHCO_3$	Tr.	14.75	....	....	4.08	16.33	2.47	1.22	....
KNO_3	....	....	15.08	....	....	....	....	Tr.	....
Soluble	19.52	3.00	41.20	14.10	31.50	.70	11.70	26.90	2.29

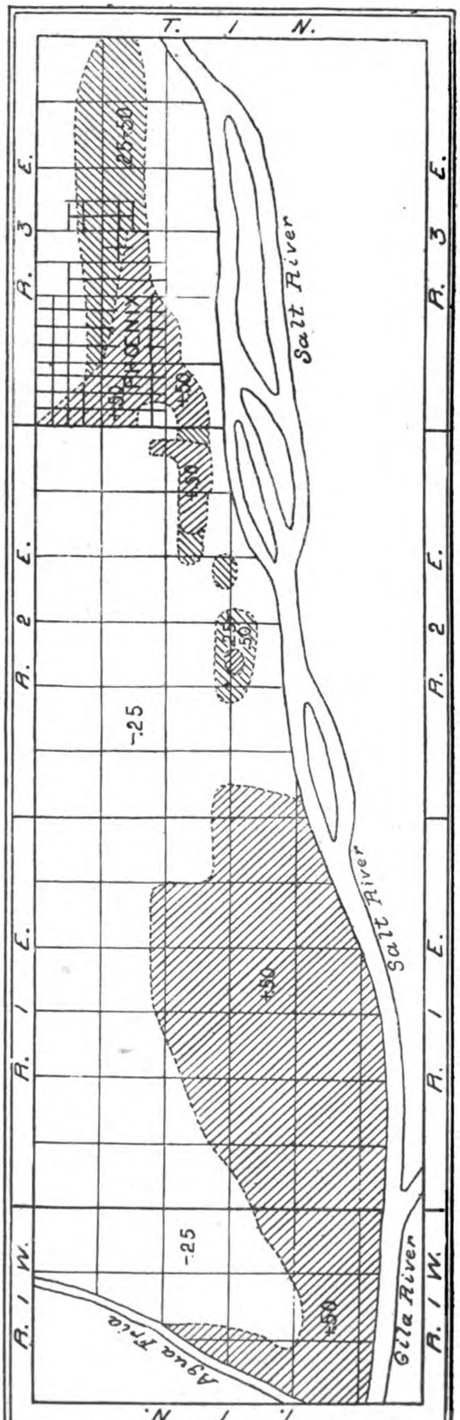


FIG. 63.—Alkali lands, Phoenix sheet, showing lands with less than .25 per cent, lands from .25 to .50 per cent, and lands over .50 per cent to depth of 5 feet.

Chemical analyses of alkali salts of Phoenix sheet—Continued.

Constituent.	4451. Sec. 15, T. 1 N., R. 1 E. (0-12 inches).	4446. Sec. 15, T. 1 N., R. 1 E. (12-24 inches).	4426. Sec. 15, T. 1 N., R. 1 E. (24-36 inches).	4450. Sec. 15, T. 1 N., R. 1 E. (36-48 inches).	4424. Sec. 15, T. 1 N., R. 1 E. (48-60 inches).	4456. Sec. 15, T. 1 N., R. 1 E. (60-72 inches).	4453. Sec. 25, T. 2 N., R. 1 E. (0-12 inches).	4449. Sec. 21, T. 1 N., R. 2 E. (0-12 inches).	4415. Sec. 11, T. 1 N., R. 3 E. (0-1 inch).
Ca	10.23	4.38	12.43	13.24	1.42	3.03	16.73	3.16	4.16
Mg	1.64	1.17	1.21	1.38	.28	.86	2.14	.56	2.36
Na	23.80	31.89	19.89	18.30	33.51	30.45	10.68	29.74	30.02
K	1.85	.58	.32	.75	.85	1.92	9.25	6.13	.94
SO_4	2.06	6.64	34.54	35.55	18.25	14.69	7.83	7.44	5.12
Cl	58.50	53.65	29.89	29.09	37.20	36.28	50.18	51.66	....
CO_3	....	....	....	....	.85	3.24	3.20	1.30	....
HCO_3	1.92	2.19	1.72	1.69	7.64	9.72	....	....	....
NO_3	....	....	....	....	....	....	....	....	Tr.
$CaSO_4$	2.92	9.44	42.14	44.96	4.81	10.14	11.04	10.59	7.21
$CaCl_2$	25.94	4.38	....	....	....	....	37.37	....	5.75
$MgSO_4$	....	....	6.00	4.76	1.42	4.10	....	....	....
$MgCl_2$	6.40	4.45	....	1.69	....	....	8.19	2.23	9.07
KCl	3.48	1.10	.58	1.38	1.56	3.24	20.29	11.70	1.80
Na_2SO_4	....	....	....	....	20.21	6.26	....	....	....
NaCl	58.63	77.64	48.91	44.89	60.11	57.20	17.44	73.23	76.18
$NaNO_3$	....	....	....	....	....	....	....	....	....
Na_2CO_3	....	....	....	....	1.42	5.62	5.69	2.23	....
$NaHCO_3$	2.63	2.99	2.37	2.33	10.47	13.41	....	....	....
KNO_3	....	....	....	....	....	....	....	....	Tr.
Soluble	2.81	2.79	3.14	3.19	1.41	.93	.56	1.07	37.52

These samples vary much in composition, but chlorides are seen to be the predominating salts. One astonishing feature is the large quantity of calcium chloride in most of the samples. The origin of this salt has been considered. In an average of the eighteen samples examined 14.4 per cent of calcium chloride was found. With the exception of calcium sulphate the sulphates are low in the crusts, nearly all of the material being chlorides. In one sample, which was collected from the loam area west of Phoenix, a large quantity of nitrates was found. Sample No. 4416 shows an analyses of a sample in which was found 20 per cent sodium nitrate and 15 per cent potassium nitrate. The nitrate spots are small and are generally found in the lower edges of irrigated fields on little ridges or elevations which are not covered by water. The soil is reddish brown and very sticky. These nitrate spots are usually limited to areas of a few feet, and are not shown upon the alkali map unless they fall within some other alkali area.

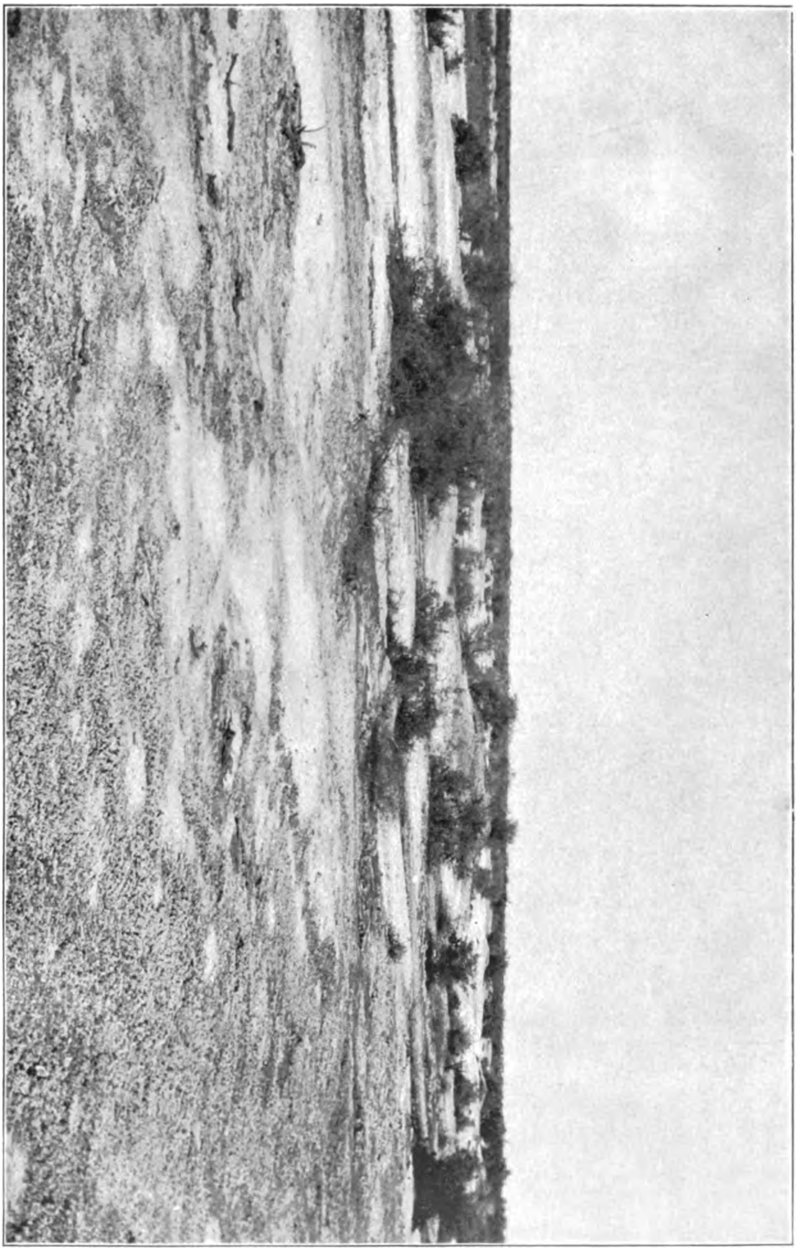
The alkali of the Phoenix area is confined to land near the river. As a rule, the uplands are free from alkali. The salts which have been leached out of the uplands have been carried down and are now appearing in the lower lands near the trough of the valley. Here the water in wells has risen slightly and carried the salt a little nearer the surface. The alkali, which is now near the surface of the

ground, was, before irrigation began, distributed in the depths of the soil. So soon as irrigation thoroughly wet the soil the capillary movement began to carry the alkali salts to the surface. Perhaps the greatest change has taken place under the St. Johns Canal. Here the land was considered free from alkali until a heavy flood soaked the ground and started the upward capillary movement of the salts. At present the greater part of the land below this canal is too alkaline for alfalfa. This being the lowest point of the valley, it naturally receives the seepage from the entire valley and here is found the maximum accumulation of alkali.

The same general principles apply in the reclamation of the alkali soils of the Phoenix area as were outlined for the Tempe area. The areas of land which are so badly alkaline offer excellent opportunity for the date palm. This is particularly true of the St. Johns country.

BUCKEYE SHEET.

The Buckeye sheet is long and narrow. The southern part is low and contains soils of great capillary power. The large draw, which has been described as being possibly an old channel of the Agua Fria River, is lower than the land between it and the Gila River, and has in particular suffered from alkali. Thus, the alkali map (fig. 34) shows a long narrow strip of bad alkali land flanked on each side by land free from excessive amounts of salts. The dividing line between the good and the bad land is sharply drawn, and there is very little land which could be called half way between the two conditions. The water underlying the draw, or at least its center, has been seen to be good when compared with the waters on either side of the zone; and yet the evaporation of these waters, augmented no doubt by occasional floods, has given rise to the quantities of alkali upon the surface of the ground. South of this draw is an area of Gila fine sandy loam elevated above the draw, level, and of excellent quality. Though it contains small quantities of alkali salts in the virgin condition, no accumulations of alkali have occurred from irrigation. North of the draw the sandy loams are porous, the slope great toward the river, and the drainage good. Alkali salts which have been leached from this land have in part gone to increase the salt content of the lower fine sandy loams.



ALKALI FLAT PRODUCED BY SUBIRRIGATION FROM CANALS AND HIGHER IRRIGATED LANDS BELOW ST. JOHNS CANAL, PHOENIX AREA.

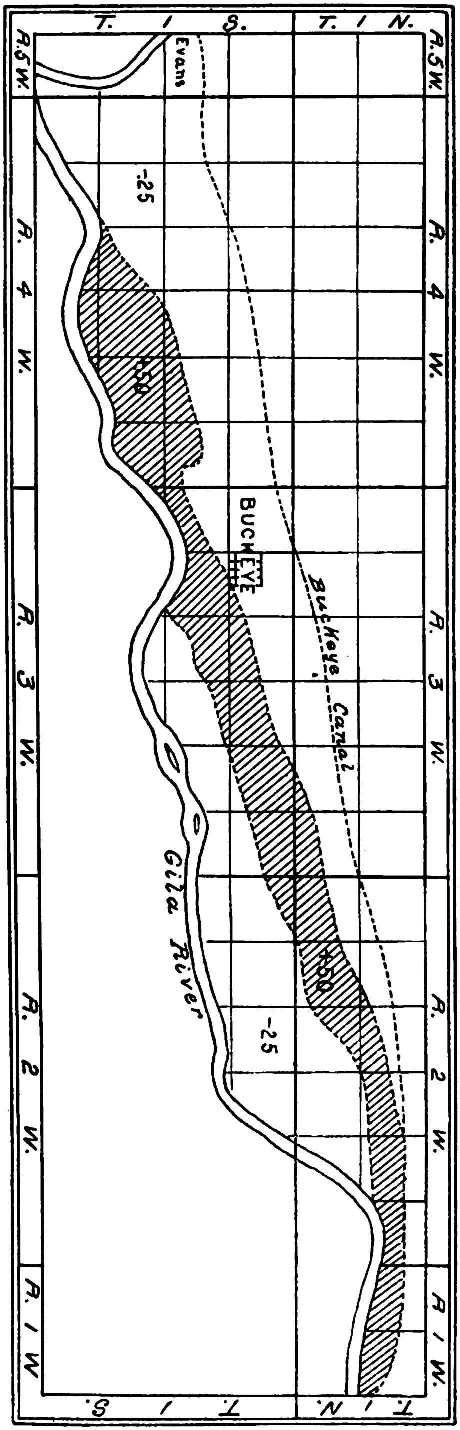


FIG. 34.—Alkali lands, Buckeye sheet, showing lands with less than .25 per cent and lands with more than .50 per cent.

The chemical composition of the alkali of the Buckeye sheet is seen from the following analyses:

Chemical analyses of alkali salts of Buckeye sheet.

Constituent.	4414. Sec. 25, T. 1 N., R. 1 W., crust.	4425. Sec. 19, T. 1 N., R. 1 E., crust.	4536. St. Johns head gates, crust.	4427. Sec. 25, T. 1 N., R. 1 W., crust.	4529. Sec. 7, T. 1 S., R. 3 W., 0–1 inch.	4508. Sec. 15, T. 1 S., R. 4 W., crust.	4518. Sec. 8, T. 1 S., R. 3 W., crust.	4533. Sec. 6, T. 1 S., R. 2 E, 0–12 inches.	4543. Sec. 15, T. 1 S., R. 4 W., crust.	4517. Sec. 34, T. 1 N., R. 2 W., 0–31 inches.	4520. Powers Butte, crust.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Ca	0.15	0.18	0.77	2.66	2.55	0.12	0.07	3.47	0.36	5.11	4.00
Mg			.28	1.63	1.98	.20	.16	1.28	.62	2.96	1.97
Na	38.09	38.02	30.15	33.50	25.45	29.90	30.75	24.01	26.98	11.03	30.92
K			10.16		8.48	13.67	9.64	12.19	13.14	24.19	.27
SO_4	8.78	9.78	3.29	1.54	18.66	19.53	13.45	5.81	18.39	4.30	7.62
Cl	45.06	40.40	53.88	60.67	39.50	30.09	41.64	52.55	30.53	46.24	54.84
CO_3	4.59	9.50	1.46		3.39	6.50	4.28	.85	9.99	6.18	
HCO_3	3.34	2.12									.38
$CaSO_4$	.50		2.60	2.17	8.58	.39	.22	8.22	1.22	5.91	10.78
$CaCl_2$				5.65				2.90		9.68	2.28
$MgSO_4$		.90	1.42		9.80	1.00	.79		3.09		
$MgCl_2$				6.28				4.96		11.56	7.72
KCl			18.52		8.77			22.95	1.67	45.97	.51
Na_2SO_4	12.47	13.32				16.52	1.21				
NaCl	74.32	66.22	74.23	85.90	58.34	49.65	68.73	59.43	49.07	15.86	78.20
Na_2CO_3	8.11	16.66	2.56		5.94	11.49	7.57	1.49	17.65	11.03	
$NaHCO_3$	4.60	2.90		Tr.							.51
KSO_4			.69		8.58	20.95	21.47		27.28		
Soluble			4.93		2.12	13.75	47.31	2.82	6.09	.74	20.59

The presence of black alkali is general in the Buckeye district, but since in every case there is an excess of white salts the application of gypsum to neutralize the sodium carbonate is useless.

Drainage is the most urgent requirement of the alkali soils. One large drainage line down the center of the alkali draw should be constructed, and such lateral drains as experience shall prove necessary. Encroachments have already been made into the edge of the alkali district with success. The only obstacle now remaining is the slow removal of the excess of underground waters which result from heavy irrigation. Date palms could probably be grown in the whole of the draw if care were used in starting them.

The water supply at Buckeye is permanent and sufficient for the entire area under the ditch, and judging from the success which has attended farming operations under this canal this draw offers one of the most attractive fields for reclamation. The distance from market renders the raising of cattle the best industry for the people, and this alkali draw could be rapidly seeded to Australian salt bushes, and while part of it was being reclaimed the remainder could pay interest as pasture land.

AGRICULTURE IN SALT RIVER VALLEY.

Southern Arizona possesses a semitropical climate in which the cultivation of fruits able to withstand small amounts of frost is possible. The number and severity of frosts, however, is not sufficient to injure certain classes of subtropical fruits.

Fruit growing is unquestionably a profitable branch of farming, and the cultivation of oranges, lemons, and such semitropical fruits is perhaps the most profitable branch of fruit growing, especially in a semitropical climate. The tendency, therefore, has been to extend fruit farming. Owing to the difficulties in the way of marketing fruit, this industry has not been largely increased in the past few years. At present the industry is centered on alfalfa, grain, and cattle. Cattle raising is perhaps the oldest agricultural industry of the valley. The uncertainty of the range country in dry seasons and the difficulty of fattening cattle on the range has led to the growing of alfalfa and other forage crops and the fattening of cattle for market. As a branch of this industry, dairying has sprung up to supply the market demands. These three industries will be considered separately.

FRUIT FARMING.

Oranges.—The orange industry of the Salt River Valley is as yet in its infancy. Only a few orchards of any size are in bearing, but the success obtained by these has started a rapid development, and orange groves are rapidly being set out. The district considered most favorable for oranges lies along the base of Camelback Mountain and the Phoenix Mountains. Here the frost is least and the daily range of temperature the smallest. No complete losses have ever been experienced from frost, for the fruit ripens early and is off the trees before the frost comes, yet on two occasions the trees have been damaged.

One great advantage which orange groves here have over southern California orange groves is the date of ripening. Arizona oranges ripen in time for the Thanksgiving market and for this reason have the advantage of high prices. The larger part of the fruit is marketed by Christmas.

The orange belt is no doubt capable of extension over a much larger area than is at present supposed to be orange territory. Great care should be given to the selection of orange lands, for there are certain areas not suited to orange culture.

Vineyards.—The warm dry climate is eminently suited to the production of fine grapes. Raisin and wine grapes have been planted in great quantities and the vineyards have been a success in every way except financially. This failure is not the result of any deficiency in the country, climate, or soil, but it is the high freight rates which practically prohibit the shipping of dried fruits out of the Territory.

Raisins of a fine quality can be grown, and as soon as the shipment to outside markets is possible a great field will open here. Wine grapes are raised and a few small wineries are in operation.

Figs.—Figs are grown, but the cost of labor in handling them and the freight rates out of the Territory make the industry a financial failure.

Stone fruits.—The growing of stone fruits is another industry held down by the cost of labor and freight rates. Excellent fruits of this class are grown, but the trade is largely within the Territory. Almonds, when they escape the late frosts, are profitable, and olives, which are weighty in proportion to their value, may prove a success financially.

CATTLE RAISING.

Alfalfa growing and cattle raising go together. Alfalfa is the most profitable forage plant, and cattle raising is considered the most profitable general agricultural industry in the Salt River Valley.

Alfalfa does well upon all classes of land except certain tracts of very heavy land or land underlain by an impervious hardpan. Such land is infrequent in the Salt River Valley. The practice of sowing barley with the first crop of alfalfa, and thus obtaining one cutting of mixed hay, is worthy of imitation by other irrigation districts in the West. Any excess of alfalfa hay over that required for the fattening of cattle finds ready sale in southern California markets and in the mining districts of the Territory.

DAIRYING.

The dairying industry, while not large, is important in some portions of the valley. One creamery at Tempe, two at Phoenix, and another at Mesa are in operation. The mining camps and railroad towns, as well as the local markets, use all of the dairy products of the valley, and there is yet a large field for increase in the production.

There are a number of poultry farms and apiaries in the valley, and all of them could be made profitable. The production of honey exceeds the local demand, but the high freight rates allow little profit on the honey shipped out of the Territory.

SOIL SURVEY AROUND FRESNO, CAL.

By THOMAS H. MEANS and J. GARNETT HOLMES.

INTRODUCTION.

This survey was commenced April 1, 1900, at the city of Fresno, and continued until August 9, 1900, during which time about 620

FIG. 35.—Sketch map of California, showing areas surveyed.

square miles of land were surveyed. The area mapped includes the territory between the third standard parallel south of the Mount

Diablo parallel and the fourth standard parallel south, and extending from the west boundary of range 19 east of the Mount Diablo meridian to the Kings River. (See fig. 35.) In this survey is included all of the land which is irrigated by the Upper Kings River canals west of the river. This takes in the agricultural district around Fresno and covers all of the agricultural territory directly tributary to this town. Included in this survey are some of the most important fruit lands of the San Joaquin Valley, large extents of wheat lands, and along the western and southern portions of the map are great areas of alkali lands. In the northeastern corner of the map the soils of the Sierra Nevada foothills are shown, and from these foothills the soils of the plains are shown nearly to the trough of the valley at the Fresno Slough.

CLIMATE OF FRESNO COUNTY.

Fresno County lies across the center of the San Joaquin Valley, extending from the summit of the coast range to the summit of the Sierra Nevadas. The climate of the valley is arid, with a wet season during the winter and dry season during the summer. This valley, as are all of the interior valleys of California, is warm and dry in summer, with almost cloudless days and no rain. The winters are characterized by occasional cloudy days with fogs and rain. The northern end of the valley receives a larger amount of rainfall than do the central and southern parts, the increase in rainfall down the center of the valley being uniform. The rainfall on the east side of the coast range is very slight, but upon the west side of the Sierra Nevada the precipitation is heavy. The data on the climate of Fresno County, which follow, is taken from the U. S. Weather Bureau reports.

The following table shows the mean monthly temperature for a series of years at the city of Fresno, together with data upon the frost:

Climatological data for Fresno.

MEAN MONTHLY TEMPERATURE FOR TWELVE YEARS.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l.
	Deg.	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*
1888	44.1	53.2	54.1	67.1	68.6	74.1	80.6	86.8	83.4	68.9	56.0	48.6	65.4
1889	43.6	50.5	58.4	63.5	69.6	79.5	82.6	82.2	75.6	62.8	54.1	49.1	64.3
1890	42.3	41.2	54.6	61.2	69.4	73.4	82.5	80.8	74.6	64.5	56.9	43.8	62.6
1891	45.4	48.5	54.4	59.0	67.1	73.0	83.6	83.6	74.6	67.0	56.2	43.9	63.0
1892	48.5	53.2	55.6	57.6	67.2	72.8	79.4	81.4	73.6	63.9	56.4	47.4	63.1
1893	42.8	48.4	52.2	55.9	66.9	73.2	80.8	82.0	68.4	60.8	52.8	48.4	61.0
1894	43.8	46.8	53.0	62.2	67.6	68.9	82.7	82.1	74.0	64.0	58.6	47.6	62.6
1895	45.3	52.6	53.7	60.0	67.4	77.2	79.4	80.6	70.4	66.6	52.8	43.6	62.5
1896	50.6	53.4	56.3	54.7	63.9	78.6	85.0	79.8	72.6	66.7	53.2	49.5	63.7
1897	43.7	49.2	48.6	63.5	71.7	74.3	82.8	81.8	72.8	61.2	52.0	45.1	62.3
1898	41.7	53.8	52.8	65.4	65.2	72.2	83.9	81.6	72.8	64.6	52.5	45.2	63.1
1899	50.0	51.2	54.4	61.1	63.2	78.3	81.8	75.1	77.3	60.4	54.4	43.8	62.6
Means	45.2	51.5	54.0	60.9	67.3	74.6	82.1	81.4	74.2	63.4	54.7	46.3	63.0

Climatological data for Fresno—Continued.

ABSOLUTE MAXIMUM AND DATE.

Date.	Temperature.	Date.	Temperature.
	Deg.		*Deg.*
January 15, 1893	69	August 11, 1898	113
February 20, 1896	80	September 24, 1888	111
March 6, 1899	86	October 4, 1889	98
April 25, 1898	101	November 7, 1894	82
May 21, 1892	104	December 5, 1895	71
June 30, 1891	112	Annual	114
July 1, 1891	114		

ABSOLUTE MINIMUM AND DATE.

Date.	Temperature.	Date.	Temperature.
	Deg.		*Deg.*
January 1, 1888	20	August 27, 1895	51
February 6, 1899	24	September 22, 1895	44
March 1, 1888	28	October 17, 1892	36
April 5, 1895	34	November 25, 1898	27
May 1, 1899	38	December 21, 1897	23
June 2, 1899	46	Annual	20
July 8, 1891	51		

FROST.

Year.	Last light frost.	Last killing frost.	First light frost.	First killing frost.	Year.	Last light frost.	Last killing frost.	First light frost.	First killing frost.
1888	Mar. 6	Mar. 1	Nov. 7	None.	1895	Mar. 21	Apr. 5	Nov. 22	Nov. 23
1889	Feb. 20	Feb. 19	Nov. 6	Dec. 21	1896	Apr. 15	Mar. 1	Nov. 26	Nov. 29
1890	Mar. 27	Apr. 14	Nov. 9	Dec. 6	1897	Mar. 23	Mar. 30	Nov. 16	Nov. 26
1891	Apr. 8	Mar. 29	Oct. 2	Dec. 3	1898	Mar. 27	Mar. 22	Nov. 7	Nov. 21
1892	Apr. 18	Mar. 28	Nov. 15	Nov. 25	1899	Apr. 29	Feb. 7	Dec. 10	None.
1893	Apr. 13	Mar. 13	Nov. 16	Nov. 18	Average	Apr. 1	Mar. 15	Nov. 16	Dec. 1
1894	Apr. 17	Mar. 4	Dec. 14	Dec. 2					

There is very little variation in the mean annual temperature or even in the mean monthly temperature between the stations in the valley. The stations along the foothills average a little higher in winter temperature than the stations of the valley, but with that exception there is very little difference. In the mountainous districts the temperature is known to be much lower, though no records are available for publication.

With this high summer temperature there is a low relative humidity, which, with the good wind velocity, makes the sensible temperature much lower than would be supposed from an examination of the temperature data alone.

Average monthly relative humidity at Fresno for twelve years.

	Per cent.		Per cent.
January	79	July	33
February	70	August	34
March	68	September	42
April	58	October	56
May	51	November	65
June	41	December	82

The prevailing direction of the wind in the valley is from the northwest, that is, up the valley. The winds are uniformly light; very few winds of high velocity.

Hourly wind movement at Fresno, 1895 to 1898.

	Miles.		Miles.
January	4.6	August	6.2
February	4.7	September	5.4
March	5.5	October	4.1
April	6.5	November	3.9
May	7.3	December	3.4
June	7.5		
July	7.0	Year	5.5

Highest wind velocity per hour and direction for twelve years.

Month.	Year.	Velocity.	Direction.	Month.	Year.	Velocity.	Direction.
January	1898	32	NW.	July	1893	24	NW.
February	1894	30	NW.	August	1891	24	NW.
March	1896	38	SE.	September	1899	28	NW.
April	1894	30	NW.	October	1892	25	NW.
May	1894	30	NW.	November	1892	30	SE.
June	1891	30	NW.	December	1891	24	NW.

The details of precipitation of the valley lands are shown by the records from Fresno. The rains are confined almost entirely to the winter months and fall in gentle showers rather than in torrents. The great part of the rainfall enters the ground and does not wash over the surface.

Monthly and annual rainfall for eighteen years.

[An accurate record of rainfall was kept by Louis Enstein from August, 1881, to August, 1887; measurements were made with a standard rain gage. Weather Bureau records began in August, 1887.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1882	0.54	1.44	1.80	1.36	0.21	0.00	0.00	0.00	0.56	1.07	1.00	0.42	7.89
1883	0.54	0.27	3.28	1.01	1.69	0.00	0.00	0.00	0.05	1.17	0.17	0.56	8.69
1884	2.54	4.35	3.77	3.42	1.43	1.25	0.00	0.00	0.00	0.46	0.08	3.93	21.23
1885	0.63	0.00	0.76	1.32	0.02	Tr.	0.00	0.00	0.00	0.11	9.54	2.06	14.44
1886	2.82	0.68	1.34	2.87	0.03	0.00	0.00	0.00	0.00	0.57	0.80	0.44	9.55
1887	0.40	3.09	0.17	2.93	0.08	0.04	0.00	0.00	0.49	0.15	0.32	1.16	8.78
1888	1.75	0.13	1.95	0.22	0.56	Tr.	Tr.	Tr.	0.06	0.00	2.38	1.71	8.76
1889	0.34	0.32	2.07	0.54	0.57	0.00	0.00	Tr.	0.00	3.17	1.89	3.87	12.27
1890	2.12	0.80	1.04	0.17	0.45	0.00	0.00	Tr.	1.26	0.00	0.22	2.30	8.36
1891	0.88	2.24	0.81	0.49	0.03	0.02	0.00	0.00	0.27	0.00	0.21	3.99	8.94
1892	0.48	1.00	1.69	0.79	1.44	0.06	0.00	0.00	Tr.	0.34	0.39	2.56	8.75
1893	1.04	2.21	4.22	0.34	Tr.	0.00	Tr.	0.00	0.01	0.02	0.16	1.40	9.40
1894	2.27	2.02	0.29	0.10	1.16	1.16	Tr.	Tr.	0.75	0.37	0.27	4.09	12.48
1895	4.14	1.70	1.84	0.99	0.52	0.00	Tr.	Tr.	0.07	0.16	0.19	0.78	10.39
1896	2.89	0.06	1.21	2.82	0.02	0.00	0.07	0.15	0.06	1.28	1.46	1.00	11.02
1897	1.93	2.65	1.64	0.30	0.00	Tr.	0.00	Tr.	Tr.	1.19	0.22	0.48	8.41
1898	0.42	1.15	0.71	0.00	0.79	0.00	0.00	0.00	1.12	0.03	0.34	0.43	4.99
1899	1.92	0.02	2.90	0.36	0.06	0.66	0.00	0.00	0.00	2.01	1.52	1.09	10.54
Average	1.54	1.34	1.75	1.11	0.50	0.18	Tr.	0.01	0.26	0.67	1.15	1.79	10.27

Greatest precipitation in twenty-four hours for each month.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1888	0.95	0.13	1.05	0.20	0.31	Tr.	Tr.	Tr.	0.06	0.00	1.33	0.71
1889	0.29	0.53	0.55	0.32	0.33	0.00	0.00	Tr.	0.00	1.73	0.48	0.75
1890	0.74	0.30	0.33	0.15	0.43	0.00	0.00	Tr.	1.12	0.00	0.22	1.21
1891	0.54	0.50	0.26	0.29	0.02	0.02	0.00	0.00	0.27	0.00	0.21	2.10
1892	0.24	0.38	0.53	0.43	0.82	0.06	0.00	0.00	Tr.	0.32	0.22	0.66
1893	0.39	1.48	1.22	0.32	Tr.	0.00	Tr.	0.00	0.01	0.02	0.15	0.55
1894	1.28	0.62	0.20	0.07	0.94	0.74	Tr.	Tr.	0.75	0.28	0.27	1.12
1895	1.46	0.95	0.52	0.84	0.52	0.00	Tr.	Tr.	0.06	0.13	0.12	0.40
1896	1.05	0.06	0.50	1.68	0.02	0.00	0.06	0.15	0.06	1.28	1.01	0.56
1897	0.73	1.16	0.50	0.30	0.00	Tr.	0.00	Tr.	Tr.	0.48	0.13	0.25
1898	0.17	0.49	0.30	0.00	0.74	0.00	0.00	0.00	1.12	0.03	0.34	0.32
1899	0.84	0.02	0.99	0.31	0.06	0.60	0.00	0.00	0.00	0.85	0.72	0.36

Monthly precipitation, greatest and least.

Month.	Year.	Precipitation.	Month.	Year.	Precipitation.
		Inches.			*Inches.*
January	1895	4.14	January	1889	0.34
February	1884	4.35	February	1885	0.00
March	1893	4.22	March	1887	0.17
April	1884	3.42	April	1898	0.00
May	1883	1.69	May	1897	0.00
June	1894	1.16	June	Many years.	0.00
July	1896	0.07	July	Many years.	0.00
August	1896	0.15	August	Many years.	0.00
September	1890	1.26	September	Many years.	0.00
October	1889	3.17	October	1890	0.00
November	1885	9.54	November	1884	0.08
December	1894	4.09	December	1882	0.42

The rainfall varies greatly in different places in the valley. In a general way the rainfall is less as one goes south or west from Fresno. Rainfall records for a number of stations are shown in the following table:

Rainfall in San Joaquin Valley.

	Precipitation.		Precipitation.
NORTH AND SOUTH.	*Inches.*	EAST AND WEST.	*Inches.*
Stockton	15.54	Mendota	5.41
Merced	10.19	Fresno	10.12
Fresno	10.12	Pollasky	11.90
Kingsburg	8.70	Huron	4.92
Tulare	7.40	Kingsburg	8.70
Bakersfield	3.58	Sanger	10.32

The records show a variation from 3.5 inches at the south end of the valley to 15.5 inches at the north end. The two lines across the valley show a variation from 5.4 to 11.9 and 4.9 to 10.3 inches in going from the west side to the eastern edge of the east side near the foothills. There is a rapid increase of rainfall as one ascends the Sierra Nevadas. There are no records from mountain stations in Fresno County, but records collected along the line of the Central Pacific Railroad from Sacramento eastward across the mountains show a gain of 1 inch in rainfall for every 85 feet in elevation up to an elevation of about 3,500 feet. Above this elevation there is no increase in rainfall as the mountains are ascended. In fact, from the observations available the rainfall lessens above 3,500 feet in elevation.

On the east side of the mountains the rainfall is much less than on the west side. Truckee, at an elevation of 5,800 feet, receives a rainfall of 27 inches, while Cisco, on the west side, at an elevation of 5,000 feet, receives a rainfall of 48 inches.

The evaporation records are few in number; the only complete data are four years' records from Kingsburg by the California State engineers.[1]

Evaporation at Kingsburg.

Month.	1881-82.		1882-83.		1883-84.		1885-86.		Average.	
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
November	2.64	4.02	1.38	1.20	2.04	1.68	2.40	1.44	2.11	2.09
December	.60	1.44	1.02	1.08	.96	.78	2.16	1.68	1.19	1.24
January	1.08	2.40	.72	.48	1.26	.90	.12	.12	.79	.97
February	1.38	1.26	1.20	.84	.60	.72	1.68	1.56	1.21	1.09
March	2.16	3.18	3.66	3.72	1.08	1.26	2.88	2.64	2.45	2.71
April	3.12	5.22	3.24	3.12	1.92	2.16	1.92	3.24	2.56	3.43
May	3.66	10.02	1.92	3.72	3.84	4.80	4.08	7.92	3.37	6.61
June	5.70	11.28	6.00	10.20	3.56	6.06	7.92	9.72	5.80	9.31
July	7.92	12.90	9.12	11.64	4.56	8.05	8.52	10.80	7.53	10.85
August	7.98	10.50	11.04	11.64	4.44	8.04	11.16	11.16	8.65	10.34
September	5.70	6.90	8.76	8.46	3.84	6.24	7.68	7.92	6.48	7.38
October	1.62	2.34	4.80	3.48	4.20	3.72	5.64	4.32	4.07	3.47
Year	43.56	71.46	52.86	59.58	32.28	44.40	56.16	62.52	46.21	59.49

The number of clear days, cloudy days, rainy days, and fogs are shown in the following tables. The months of August and September, during which raisins are being dried, are seen to be very clear. During the winter months fogs are frequent, keeping down the evaporation from the soil.

Clear, cloudy, and rainy days, by months.

Month.	Average number of—				Month.	Average number of—			
	Clear days.	Partly cloudy days.	Cloudy days.	Rainy days.		Clear days.	Partly cloudy days.	Cloudy days.	Rainy days.
January	9	8	14	8	August	25	6	0	0
February	15	7	6	6	September	25	3	2	1
March	13	10	8	8	October	20	7	4	3
April	19	8	3	3	November	17	7	6	4
May	21	7	3	3	December	9	9	13	9
June	26	3	1	1	Annual	230	76	59	44
July	29	2	0	0					

Foggy days in twelve years, by months.

Month.	Total foggy days.	Average.	Month.	Total foggy days.	Average.
January	144	12	July	0	0
February	44	4	August	1	0
March	25	2	September	4	0
April	3	0	October	15	1
May	0	0	November	75	6
June	0	0	December	160	13

[1] Physical Data of California.

GEOLOGY AND TOPOGRAPHY.

Fresno County is naturally subdivided into two portions—plains and mountains.

The plains are the bottom of the San Joaquin Valley extending from the foot of the coast range on the west to the foothills of the Sierra Nevada on the east. The trough of the valley south of Fresno has an elevation of 180 feet, Fresno has an elevation of 290 feet, and the valley, at the edge of the foothills, has an elevation of about 500 feet. The distance from the slough in the lowest part of the valley to the foothills is about 35 miles, so that the average slope is about 9 feet per mile. The greater part of this fall is between Fresno and the foothills, for the average maximum fall from Fresno to the sloughs is only 5 feet per mile.

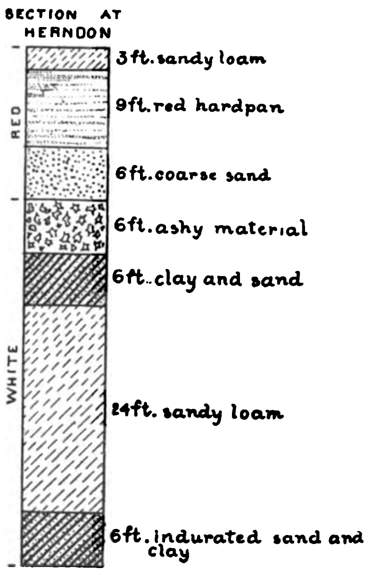


FIG. 36.—Section of bluff at Herndon, Cal.

The maximum slope is southwest, about at right angles to the main line of the Southern Pacific Railroad.

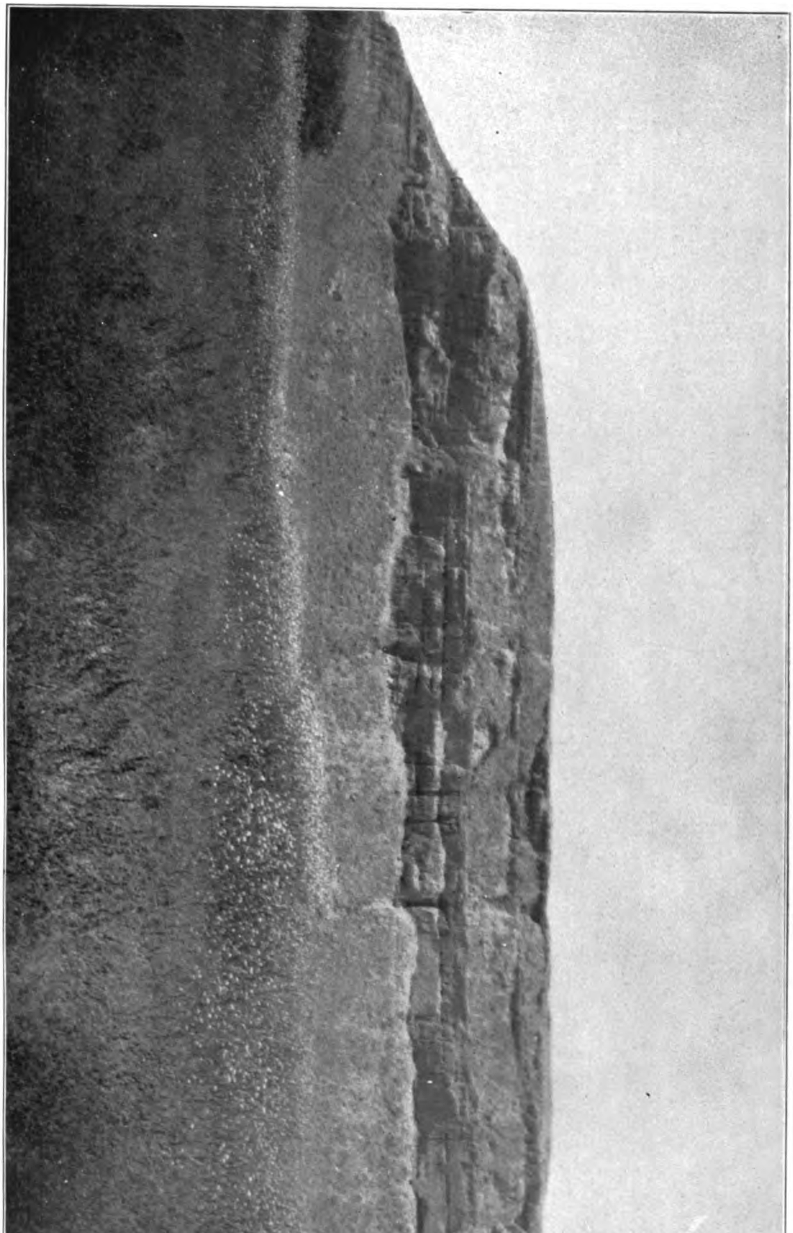
From the first foothills the rise is rapid, the mountains culminating in peaks 10,000 to 12,000 feet high. Mount Whitney, a little to the south, is the highest mountain in the United States—about 15,000 feet.

The plains are the débris from the wearing down of the mountains on both sides of the valley, but, since the eastern mountains are much higher, have a greater run-off of water, and larger drainage area, the portion of the valley which is shown on the map is entirely débris from the Sierra Nevadas.

The plains are formed of well-stratified deposits—clays, sands, gravels, volcanic ash, and sandstone—laid down under water at some time when the portion of California now included in the Great Valley was lower in elevation than at present and was an arm of the Pacific Ocean.

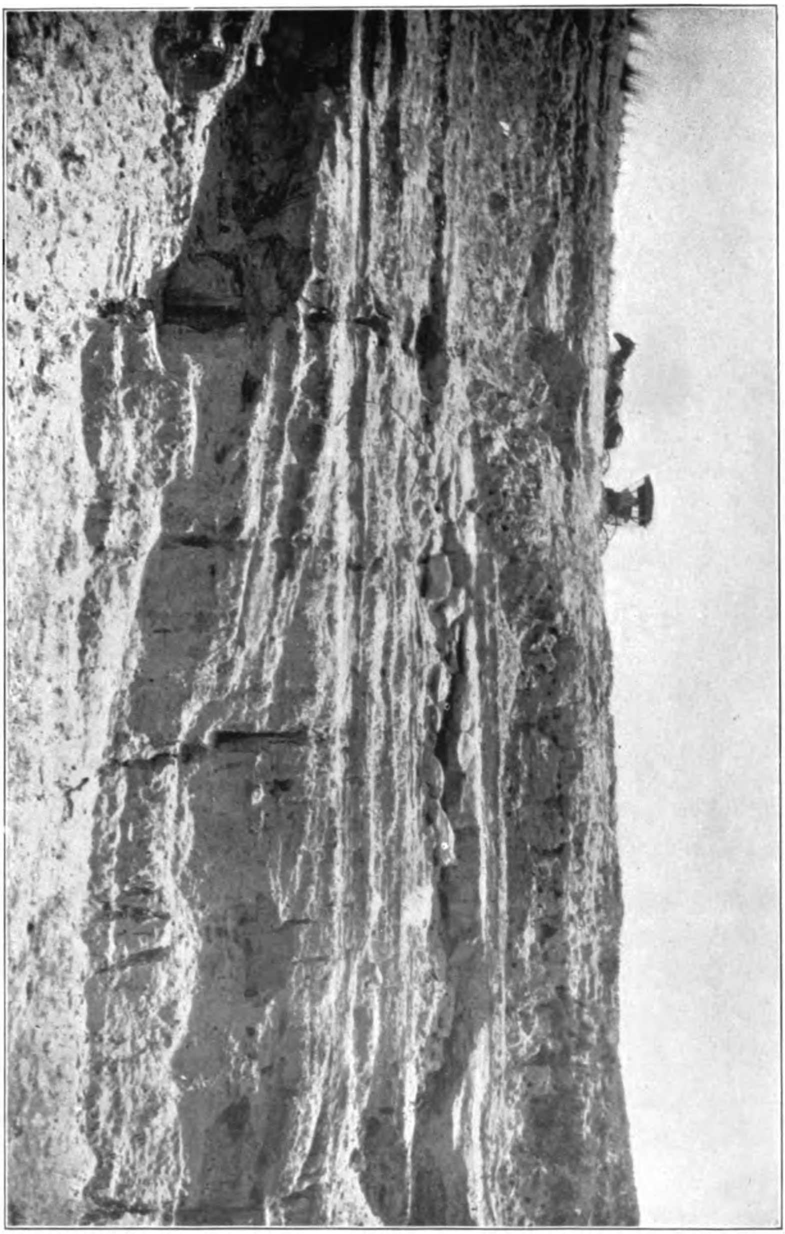
Typical sections of the valley deposits are exposed in the bluffs along the San Joaquin River and along the Kings River and in wells in the plain portion of the valley.

Two geologic sections are shown in figs. 36 and 37. At Herndon a vertical section of the bluff shows 18 feet of the red material from which the San Joaquin sandy loam has been derived. The soil of 3 feet in depth is underlaid by a red sandstone, which, from its presence immediately below the surface, is called hardpan. This hardpan is an indurated sand in which the cementing material is



RED SANDSTONE BLUFF ALONG SAN JOAQUIN RIVER ABOVE LANES BRIDGE.

This sandstone forms the hardpan which underlies the lands north of Fresno.



BLUFF OF WHITE FORMATION AT LANES BRIDGE ON THE SAN JOAQUIN RIVER.

This formation consists of white sands, sandy loams, and volcanic ash, interstratified with soft lime-magnesium hardpan, and always contains white and black alkali.

hydrate of iron and silica. Below this sandstone is found a bed of coarse red sand 6 feet in depth. Underlying the sandstone is a bed of volcanic ash 6 feet thick, and this in turn is underlaid by sandy loams, clays, and ashy material as deep as exposed in the bluffs.

At Lanes bridge, 11 miles north from Fresno, the red materials are much thicker, there being two distinct strata of the red sandstone. As at Herndon, the red materials are underlaid by the white ashy materials. On going farther up the San Joaquin, beds of gravel are encountered on top of the red sandstone. In some exposures these gravels are pumice, so light as to float when dry. Following the river still farther up, the gravel is found overlying the granite foothills, and upon the gravel is a basaltic table-land, sloping southwest at the rate of about 100 feet per mile.

A section along this line is shown in fig. 38 and another along a different line in fig. 39. The white formation is seen to be the lowest exposed strata. This is overlaid by the red formation, and in the foothills, with a few remnants out in the valley, is found the basaltic table-land.

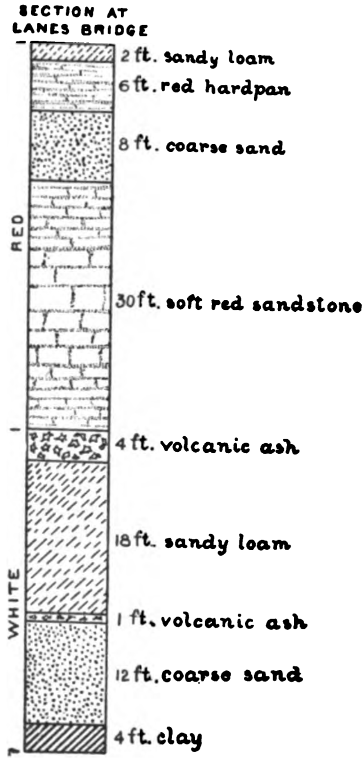


FIG. 37.—Section of bluff at Lanes Bridge, Cal.

The material comprising the red soils north of Fresno is intimately connected with the basaltic lava flow. The sandstones, as far as can

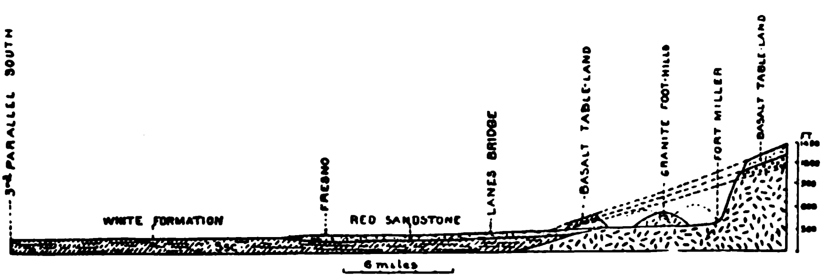


FIG. 38.—Section north and south through Fresno, across Fresno sheet to San Joaquin River at Lanes Bridge, thence northeast to foothills.

be judged from microscopic examination, were formed from the breaking down of basaltic and granitic material.

The presence of the iron in the basalt and the presence of iron in

the red soils indicates a relation between these two materials, since there is no other rock from which the iron could have originated in such quantities. This basalt table-land undoubtedly extended over a much larger area than is at present covered, for remnants of the table are seen far out in the valley northwest from Millerton.

Underlying this red material are strata of white sands, loams, and clays, interstratified with volcanic ash. In places the ash becomes coarse in texture and there are exposed in the portions near the foothills gravel banks composed entirely of pumice.

These materials are well stratified and were laid down in deep water. Everywhere throughout the exposures alkali salts are found associated with the white strata in the unconsolidated material or in the white or bluish lime-magnesian hardpan which is found interstratified with the sands and volcanic ash. This is in contrast with the red strata, which are everywhere free from alkali salts. If the red materials ever contained alkali salts this has all been removed by water. The soils formed from these two formations resemble the original material

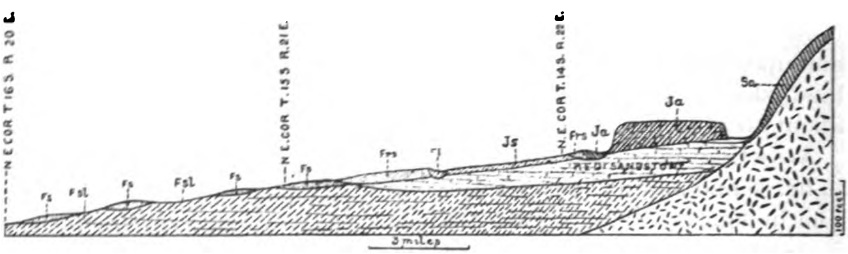


FIG. 39.—Section from foothills in northeast corner of Fresno sheet, SW. to NE. corner T. 16 S., R. 20 E.: *Fs*, Fresno sand; *Fsl*, Fresno sandy loam; *Frs*, Fresno red sand; *Fl*, Fancher sandy loam; *Js*, San Joaquin sandy loam; *Ja*, San Joaquin black adobe; *Sa*, Sierra adobe.

in this respect; the red soils are free from alkali salts and the white soils always carry alkali salts immediately at the surface or else buried at a shallow depth. These alkali salts are held by the lime-magnesian hardpan, the formation of which will be discussed later.

SOILS.

The soils have about the following area:

Areas of the different soils.

Soil.	Area.	Per cent total area.	Soil.	Area.	Per cent total area.
	Acres.			*Acres.*	
Fresno sand	163,200	40.6	San Joaquin red adobe	12,691	3.1
San Joaquin sandy loam	74,547	18.6	San Joaquin black adobe	5,664	1.4
Fresno sandy loam	69,811	17.4	Meadow	5,478	1.3
Fresno red sand	43,776	10.9	River wash	480	.1
Sierra adobe	13,376	3.3	Total	401,855	
Fancher sandy loam	12,832	3.2			

Three main physiographic and four natural soil divisions have been recognized: The foothill region, where agriculture is confined largely to grazing; the plains of the valley, with subdivisions (first, the red soils derived from the red formation and, second, the white soils derived from the sands and volcanic ash of the white formation), and the bottoms or alluvial lands along the Kings River.

SIERRA NEVADA FOOTHILL SOILS.

The classification of the soils as foothill soils is in name purely physiographic, though there is a physical difference in the soils themselves which warrants their separation as a class. The foothills are granitic, though the character of the granite changes greatly, and occasionally we have intrusions of volcanic material, which in many ways change the aspects of the soils. The agents which have acted in the weathering of these rocks also have caused differences. Of these agents in the higher mountains, insolation, or the action of the sun's rays on the rocks, and the grinding action of glacial ice are the most prominent. Glaciation has not extended to the lower foothills, as far as has been observed.

The action of water has caused the greatest part of the breaking down of the granites. The upper 2 or 3 feet are very thoroughly disintegrated with the formation of the surface soil of red adobe. Where this adobe material has been washed down into the valley along the stream courses patches of heavy brown or black adobe are frequently found, resulting from the growth of swamp vegetation in the normal foothill adobe.

SIERRA ADOBE.

By this title, "Sierra adobe," is designated the normal product of the weathering of the granite rocks of the foothills. The granite rock, yielding to the various weathering factors, slowly disintegrates and decomposes, the more easily attacked minerals giving way first. The result is a sandy loam filled with coarse sand grains and particles of rock in a half-decomposed state. These particles yield still more to the weather and there results an adobe with coarse sands and partially decomposed mineral fragments. This soil presents very markedly the characteristics of an adobe soil; that is, it is very sticky when wet, dries hard, and cracks badly. There is nothing in the mechanical composition which would indicate the peculiar adobe properties which are found, therefore it is reasonable to assume that this property is due to some peculiarity of the soil grains themselves rather than a property induced by any peculiar size of the soil grains or an arrangement of the grains. Analyses of soils similar in origin to this soil, published by Hilgard, show relative large quantities of soluble silica, alumina, and iron. This would indicate silicates which are easily decomposed or rendered soluble, and it may be these unstable silicates, in taking up and giving off the water of the soil, so change

their character as to give the soil its adobe properties. The term "adobe" does not of necessity imply a soil which carries a large percentage of clay, but it does imply a soil in which that clay is of such a character as to absorb water and swell when moistened, and to dry hard, shrink, and crack when dried.

A mechanical analysis of an average sample of this Sierra adobe is shown in the following table:

Mechanical analysis of Sierra adobe.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4861	Sec. 5, T. 13 S., R. 23 E.	0 to 12 inches....	2.79	2.80	3.14	7.16	24.50	31.10	19.65	8.82

This soil in the field possesses the properties of a much heavier soil than would be indicated by consideration of the mechanical analysis alone. The simple mechanical analysis indicates a sandy loam such as would result in normal weathering of a granite under humid conditions. However, the peculiar type of weathering produced by the climate of the Pacific coast results in the formation of a soil very different from a sandy loam in character. The reason for this peculiar type of weathering is not well understood at present.

The foothills in this portion of the San Joaquin Valley are not extensively farmed. The rainfall is insufficient to produce crops every year, and, moreover, the topography does not permit grain farming. The foothills are usually steep (up to 30-degree slope) and well rounded. Along the lower hills, when the soil has been carried out on the plains, this same type of soil is farmed successfully and dry grain in normal years produces a profitable yield.

SAN JOAQUIN BLACK ADOBE.

Whenever the Sierra adobe is washed down along the foothill stream courses, and serves as a soil for tule and other swamp vegetation, certain changes take place in the physical and chemical properties of the soil. The soil becomes brown to black by the incorporation of organic matter, and there is usually more complete disintegration of the mineral fragments and an increase in clay content at the expense of the coarser particles. This adobe assumes nearly the characters of the true black valley adobe of the slough country near the axis of the valley. Since it is an alluvial soil it is deeper than the Sierra adobe and often attains a depth of 6 to 8 feet.

The mechanical analysis of this soil is given in the following table:

Mechanical analysis of San Joaquin black adobe.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4854	Sec. 3, T. 13 S., R. 22 E.	0 to 24 inches	6.27	1.70	2.18	7.36	11.38	22.27	33.88	14.25

In some localities this soil is known as a "dry-bog" soil. This peculiarity is due to the property which the soil has of shrinking as it dries and cracking up into irregular-shaped grains. These grains vary in size from that of a small grain of sand to an inch in diameter. The soil is light in weight, and in walking over this loosely cracked material one sinks to a depth of several inches each step. This has given rise to the name of "dry bog."

A second phase of this soil occurs in one area on the map. This area is a remnant of an old delta from Kings River. The soil occupies the mesa directly north of Centerville. The mesa is from 30 to 50 feet higher than the plain of the valley immediately surrounding it. The soil is very dense and black and exceedingly stiff when dry. Throughout the surface soil are found occasional large gravel and at a depth of 3 to 4 feet the gravel is abundant.

The following mechanical analysis shows this phase of the soil to carry about twice as much clay as the Sierra adobe and about 10 per cent more clay than the normal black adobe, yet it does not indicate the stiffness and tenacity which were found in the field:

Mechanical analysis of second phase San Joaquin black adobe.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4856	Sec. 29, T. 13 S., R. 23 E	0 to 18 inches	3.76	0.70	2.40	4.48	8.78	13.88	46.06	24.42

This one area in places assumes a dry-bog character, as does the normal San Joaquin black adobe.

The area is farmed exclusively to dry grain without irrigation, since

from its position water can not be obtained for irrigation except by very expensive works or by pumping.

In the recent extensive progress in citrus-tree cultivation along the foothill border in the San Joaquin Valley this black-adobe soil has been selected as one of the most favorable soils for orange trees. The orchards are yet young and the best soils for orange culture is largely a matter for experiment, but if the experience of southern California is a guide, these soils are adapted to such culture. As dry-grain soils they are not so successful, since the cracking of the surface permits such rapid evaporation of the moisture that grains do not have sufficient time to develop before the soil dries out. This criticism, however, does not apply to a crop which can be cultivated, for this cracking is largely prevented by cultivation.

Red Formation Soils.

Under this head are included the soils derived from the red sandstone formation, which has been described. The red sandstone formation, which has been called the red formation for convenience, is believed to have been formed from the mixed granitic and basaltic débris from the mountains, and the soils are of the same origin.

FRESNO RED SAND.

The Fresno red sand, which is the lightest product of the weathering of this formation, occupies ridges and plains between the foothill creeks which leave the mountains north and east of Fresno.

The soil is very light and porous, deep generally, and uniform in character, to a depth of 6 feet. The results of mechanical analyses are shown in the following table.

Mechanical analyses of Fresno red sand.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4699	S. 27, T. 13 S., R. 20 E.	0 to 24 inches	2.11	10.13	13.20	32.75	26.72	9.90	3.82	1.35
4702	S. 32, T. 13 S., R. 20 E.	.....do	1.15	Tr.	11.82	40.38	35.69	6.70	1.99	1.69
4823	S. 4, T. 14 S., R. 21 E.	Clod	2.20	.74	11.96	26.68	27.02	13.06	12.28	5.17
4691	S. 31, T. 13 S., R. 20 E.	0 to 36 inches.	2.26	6.47	14.55	16.44	21.35	21.12	10.24	7.26
3306	S. 3, T. 14 S., R. 21 E.	0 to 24 inches	2.03	.24	5.12	20.96	41.39	18.11	4.97	7.50

The mechanical analyses show the soil to be very light in texture. Fine sand is the predominating grade, with small quantities of very fine sand, silt and clay on one side and rather large quantities of

medium sand and gravel on the other side. Such a texture indicates a very open, porous soil, one in which the natural drainage is good. Such is found to be the case in the field. The soil occupies ridges where it is deep and well drained by the beds of the foothill streams.

No chemical analyses of this soil are available, though from the field observations some facts can be gleaned. The soil is apparently well off in plant foods, with the exception of nitrogen. As in all of the plains soils around Fresno, this important plant food is not abundant.

The soil is in a well decomposed condition, that is, the soil grains are soft and easily crushed, and even though in some cases presenting apparently fresh mineral fragments, these fragments are rapidly breaking down. This decomposition undoubtedly renders available all of the plant food for the crops grown at the present time.

This soil originated in the granitic and volcanic rocks in the mountains to the eastward. The disintegrated materials were swept down to the plains of the valley by the foothill streams. These streams have built up sandy banks of red sand, and this has been still further distributed by the winds. At present the sands occupy low ridges running northeast to southwest, principally along the south sides of the foothill streams.

Fruit crops generally are grown on this soil with success. Large areas of raisin grapes are located upon it north, east, and west of Fresno, and though the soil can not be considered to be the best grape soil in the country, yet good results are obtained from its cultivation. The elevated position adapts the soil to such fruits as require specially good drainage. Figs, peaches, apricots, nectarines, plums, and prunes are the fruits best adapted to this soil, and they can be recommended in the order named. Grain is not as successful as on heavier soils, but melons of all kinds thrive and produce abundantly. North of Fresno large fields are planted in watermelons and the product shipped to the cities. The trucking industry, which is not great and which is confined to supplying the local markets, is largely located on this soil.

This light character makes cultivation easy, but the porosity of the soil renders irrigation difficult. Irrigating canals and laterals passing over areas of this soil lose large quantities of water through seepage. This water is not only lost to all good, but it is a serious menace to lands lying in the lower parts of the valley. Also in irrigating much larger quantities of water are used in flooding these porous sands than are necessary to the life of the growing crops. All this excess of water accumulates in the deeper subsoil, and runs underground to raise and make swampy some lower soil.

The irrigation of such a soil should be in small lands or small checks. Wherever furrow irrigation is possible, and in the growing of fruit crops it is always possible, this soil should be watered by the furrow method. Short furrows in which the water runs only a few

hours are much perferable to long furrows requiring several days to irrigate. Ditches, laterals, and canals should all be protected from leakage. It is believed that over one-half of the water applied to this soil is lost by seepage. If this water were saved, twice as great an area could be covered with the present supply of water, and, moreover, none of the leaching away of plant food would result and the harm to the lower lands from seepage waters would be obviated.

This soil never carries alkali salts in sufficient quantity to be harmful to vegetation.

SAN JOAQUIN SANDY LOAM.

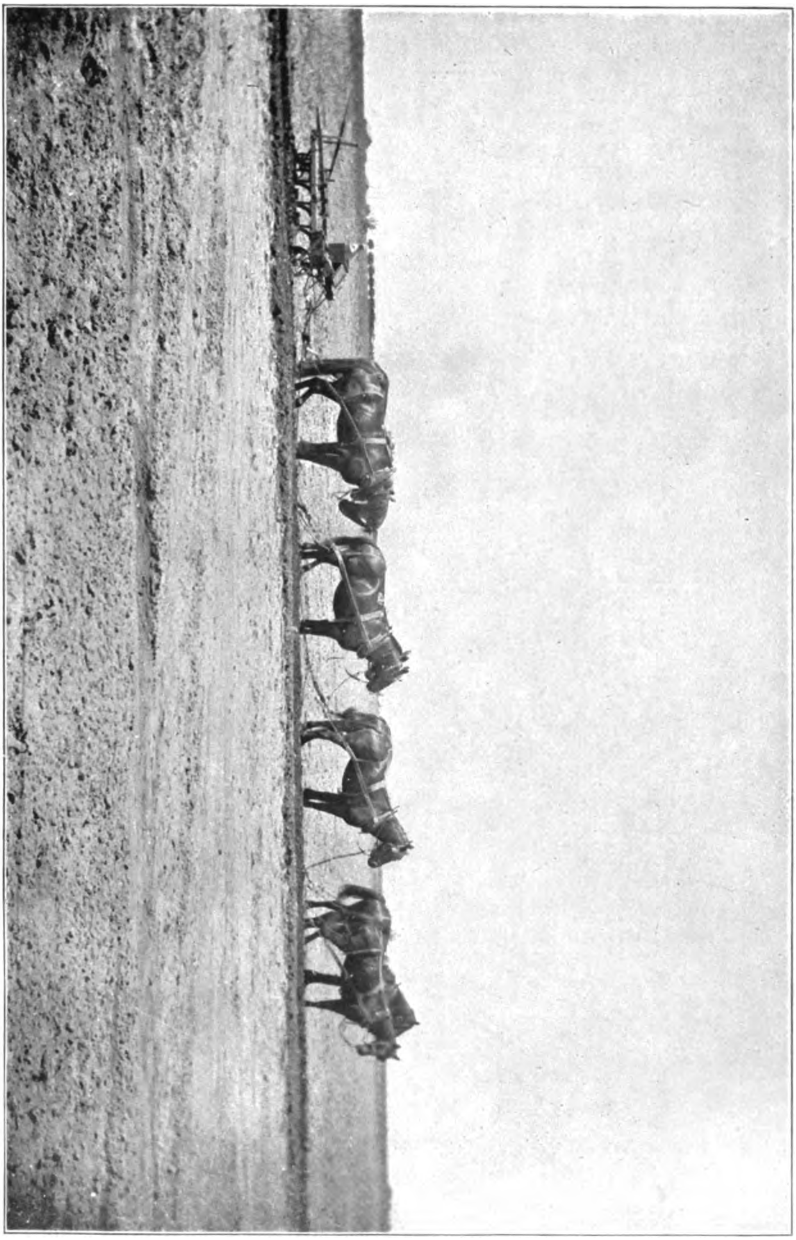
The San Joaquin sandy loam occupies great areas of land north, northwest, northeast, and east of Fresno. The soil as typically developed is seen on the "hog-wallow" lands which are found between Fresno and the San Joaquin River at Herndon. When the foothill streams are approached the same character of soil is formed by the intermixing of the Fancher sandy loam of the creek bottoms and the Fresno red sand of the ridges.

In its mechanical composition, as shown in the following analyses, the soil does not differ greatly from the red sand. The lighter phases show 5 to 6 per cent clay, and by uniform gradation the clay content increases to 14 per cent in the heavier phases. An average soil carries from 9 to 10 per cent clay.

Mechanical analyses of San Joaquin sandy loam.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4697	Sec. 4, T. 13 S., R. 19 E.	0 to 24 inches	1.77	7.59	11.30	19.26	21.01	22.60	10.83	5.94
4695	Sec. 29, T. 13 S., R. 19 E	do	1.59	12.47	15.53	14.40	12.31	22.33	13.15	7.22
4696	Sec. 10, T. 13 S., R. 19 E	do	1.81	10.22	12.95	14.18	13.98	25.51	12.55	7.95
4703	Sec. 1, T. 13 S., R. 19 E.	do	3.00	1.58	3.59	5.45	7.85	44.14	25.52	8.34
4705	Sec. 9, T. 13 S., R. 20 E.	0 to 6 inches	3.66	2.87	5.80	7.80	13.03	32.06	24.77	10.13
79c	Sec. 12, T. 14 S., R. 20 E	0 to 24 inches	2.74	1.29	4.34	13.70	22.89	19.45	25.01	10.24
327	Sec. 4, T. 14 S., R. 21 E.	do	4.86	.60	2.99	9.05	15.70	26.04	31.06	11.00
3394	Sec. 3, T. 14 S., R 21 E.	0 to 36 inches	4.13	.43	3.40	16.14	30.95	15.90	14.30	14.60

This mechanical composition indicates a light sandy loam soil of easy tillage and drainage. In this case, as in many other soils of the western districts studied, the mechanical composition does not show the true properties of the soil. It has in a measure true adobe properties, and when dry is very hard and difficult of cultivation. This property is particularly true of the hog-wallow lands. Here, when dried, toward the latter part of the dry season, the soils are exceed-



GANG PLOW PREPARING LAND FOR WHEAT UNDER DRY FARMING, SAN JOAQUIN SANDY LOAM.

ingly hard; clods plowed up in the fields remain hard and unpulverized even after careful cultivation. Just the reason of this hardening is a problem yet to be solved, though it is deemed possible that the explanation will be found in the easily decomposed silicates, which are so abundant in soils of this adobe-like class.

This soil originated much in the same way as the red sand soil, except that the greater part of its area is much older than the red sands. The larger areas are sedentary soils derived from the weathering of the red sandstone of the red formation, which underlies the soils; but since this red formation is to be regarded as wash from the mountains the soils have the same ultimate origin. Thus, the chemical and mineralogical properties of the soils should be the same. The sandy loam, however, being more finely divided, has suffered greater weathering than the sand, and in this regard should have more plant food in an available form.

Large areas of this soil are underlaid by the red sandstone hardpan. In such areas only unirrigated grain crops are grown. Wherever the hardpan is below 2 feet in depth the grain crops are fair or good; but where the hardpan approaches the surface nearer than 2 feet very little profit is obtained from the cultivation of the soil in any crop. This is seen in the cultivation of the hog-wallow lands, for on the top of the hog-wallow mounds, where the soil is usually deeper than between the mounds, the crops grow and mature grain, but between the mounds, where the soil is shallow, the crops in the early spring start well, but the shallow soil soon dries out, and before the grain matures the moisture from the soil all evaporates and the grain suffers or dies.

On the deeper soils fruit crops are grown with great success. Wherever the soil is well drained the same recommendations can be made as were made for the Fresno red sand soil, but when the land is low lying and wet drainage is necessary before fruit produces the best results. In several areas northeast from Fresno drainage is found to be necessary for fruit lands.

The areas of shallow depth to hardpan on this soil cover large extents of land which otherwise would be very valuable. No cheap or easy method of removing this hardpan has been devised, and this is one of the most serious and difficult problems of the country. A more complete discussion of the hardpans will be found later in this report.

No large areas of alkali lands are found in this soil. This is to be expected from what has been said of the alkali in the red formations from which it is derived.

FANCHER SANDY LOAM.

Along the foothill streams and around the sinks where these streams disappear in normal flow are found areas of a heavier sandy

loam, in some cases approaching a loam in texture. These soils occupy the low-lying tracts along the streams between the ridges of Fresno red sand. Since Fancher Creek has produced the most typical areas of this soil the name Fancher sandy loam has been adopted.

The mechanical analyses following show this soil to be only a little heavier than the San Joaquin sandy loam; it contains 11 per cent of clay as compared with 9 per cent in the San Joaquin sandy loam. The difference in texture is not so much due to the difference in the amount of clay as the difference in the amounts of silt and very fine sand, both of which are greater in the Fancher sandy loam.

Mechanical analyses of Fancher sandy loam.

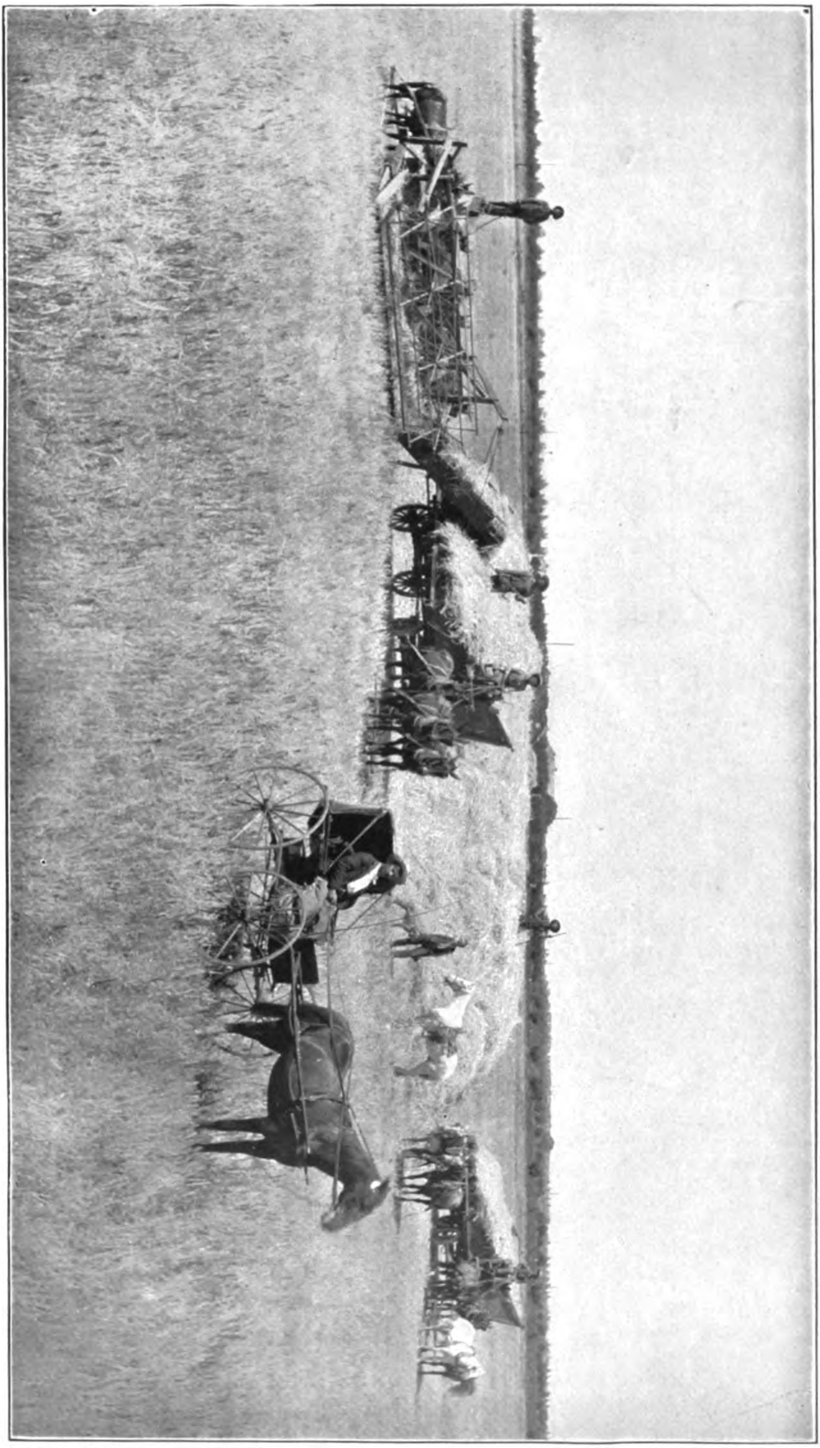
No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4830	Sec. 17, T. 14 S., R. 19 E.	0 to 24 inches	2.62	1.30	1.58	3.74	29.06	34.80	18.76	7.97
4824	Sec. 5, T. 14 S., R. 21 E.	do	3.41	.91	2.82	7.72	16.68	31.98	28.16	9.01
4845	Sec. 8, T. 14 S., R. 21 E.	do	3.22	Tr.	2.75	19.99	28.46	19.51	16.86	9.55
4841	Sec. 25, T. 14 S., R. 18 E.	0 to 12 inches	4.34	......	2.18	8.12	24.52	19.60	30.67	10.32
4825	Sec. 21, T. 14 S., R. 20 E.	0 to 24 inches	2.41	......	1.34	15.10	24.48	22.56	21.39	12.29
4700	Sec. 21, T. 13 S., R. 20 E.	do	3.83	3.99	10.57	14.20	12.66	17.43	21.24	15.87

This soil is considered to be of the same origin as the two red soils of the San Joaquin formation, which have been previously described. It is, however, directly the result of stream depositions, and for that reason carries small quantities of gravel and coarse sand. The soil areas are found along the flood courses of the foothill streams. Dry Creek, Dog Creek, Red Bank Creek, Fancher Creek, all have areas of this soil along their courses. The soil deposited by Dry Creek is typically a red, fine-grained, micaceous sandy loam of great depth. Fancher Creek deposits a soil of a heavier type, darker in color and with less mica.

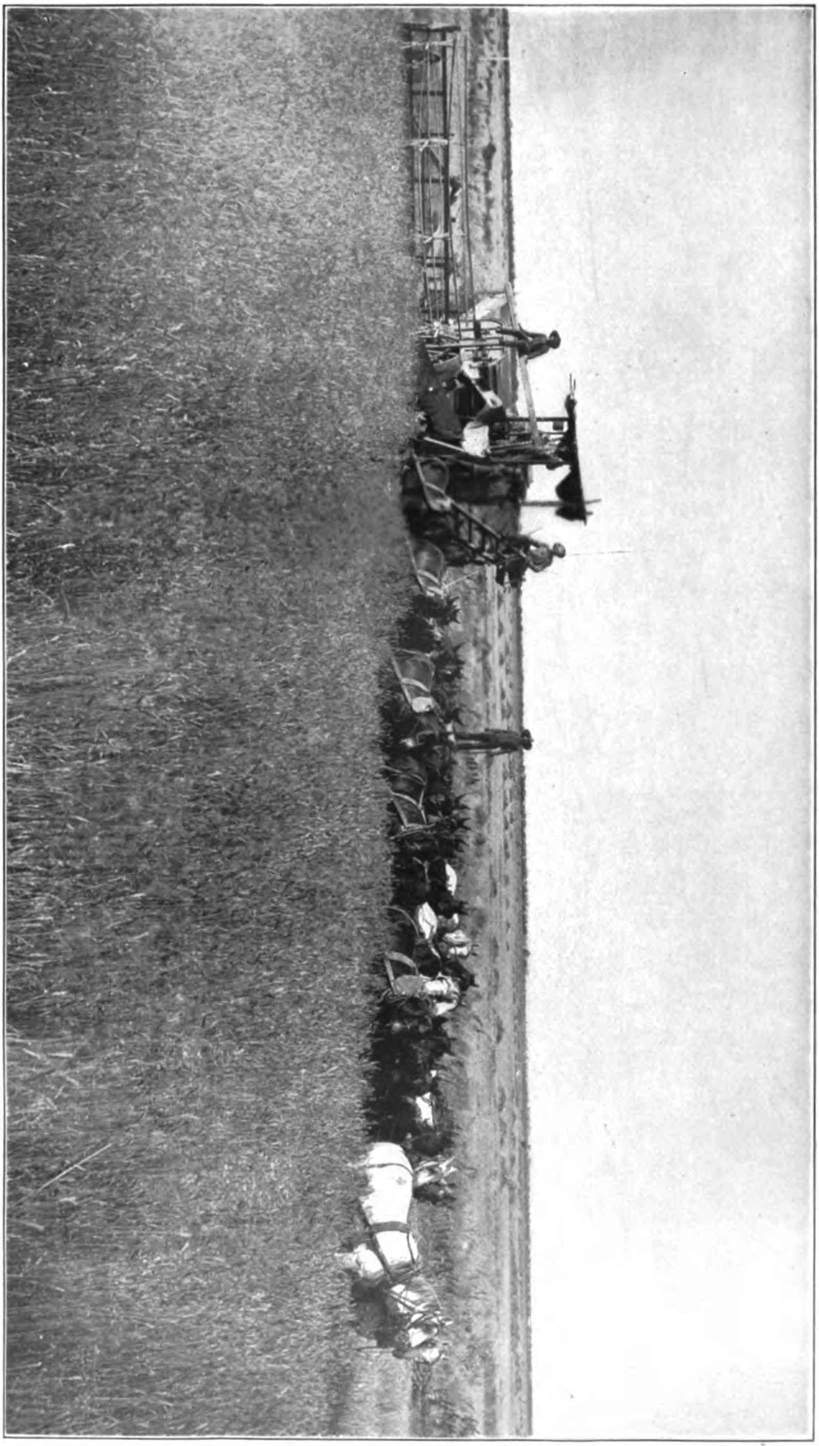
Since the soil is further weathered than either of the red soils described, the plant foods should be in a more available form. The soils contain more organic matter than do the other soils of the valley, and in this way perhaps are richer in nitrogen.

This soil is the best soil for grapes found in the Fresno sheet. Large and excellent vineyards are located on it. This soil has been examined by Hilgard, chemically, and at the World's Fair at Chicago, in 1893, a section of this soil was exhibited as a typical raisin-grape soil.

The soil is deep, generally more than 6 feet, and is easily drained. Some of the areas suffer from nearness of underground water so much that drainage has been found necessary. The soil, however, is so



HEADING GRAIN ON SMALL TRACTS. GROWN WITHOUT IRRIGATION.



HARVESTING GRAIN WITH COMBINED HARVESTER AND THRASHER ON LARGE TRACTS. GRAIN GROWN WITHOUT IRRIGATION.

porous that tile drains every three or four hundred feet are all that have been required.

No alkali areas of great size have been found in this soil with the exception of the area in the south half of T. 14 S., R. 19 E. There the soil has been pushed out across an area of alkali soil, and the alkali salts have raised in the Fancher sandy loam so as to render part of it barren. Small areas of alkali, mere spots, seldom as large as an acre, have been found along the old streams and sinks east from Fresno. These spots are not getting larger; in fact, an examination of the land around them shows no alkali in the subsoil which would make them grow larger. Such spots are merely local accumulations of alkali from the prolonged subirrigation of that particular spot of ground. Constant subirrigation, even if by a good water, will in time result in an accumulation of alkali at the surface of the ground, and since it appears that alkali salts move up much faster than they move down subirrigation leads to accumulation of the salts at the surface very rapidly.

There is no reason to fear that these spots in the Fancher sandy loam will spread or that there will be new spots formed in fields which at present are free from alkali salts. A careful study of the conditions warrants the prediction that as long as the water surface is kept down to its present level no more damage will result.

SAN JOAQUIN RED ADOBE.

In the northeastern corner of the map, along the margin of the foothills and extending for 5 or 6 miles along the ridges between the foothill creeks, are areas of a bright, red soil which has been called San Joaquin red adobe upon the soil map. Red Bank Creek receives its name from the exposures of this bright red soil along the banks.

Mechanical analyses following show very little difference between this soil and the Fancher sandy loam. In fact the average of the six samples of sandy loam is so nearly like the average of three analyses of the adobe that the differences are all within the limit of error of the method of analysis.

Mechanical analyses of San Joaquin red adobe.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4846	S. 22, T. 13 S., R. 22 E..	0 to 12 inches ...	2.29	0.97	5.01	12.65	23.29	21.71	24.83	10.05
4848	S. 23, T. 13 S., R. 22 E..	.....do..........	2.65	1.56	3.66	10.52	23.80	26.04	21.10	10.48
4850	S. 22, T. 13 S., R. 22 E..	.....do..........	3.03	.70	4.90	13.16	22.34	18.78	25.90	11.18
4851	Subsoil of 4850.......	12 to 24 inches ..	3.07	Tr.	4.17	10.86	18.92	17.36	26.27	18.86

The analyses of these two soils types, the Fancher sandy loam and the San Joaquin red adobe, serve to illustrate the fact that the mechanical analysis alone can not be relied upon to tell the character of the soil in the field. Here we have analyses so nearly the same that the soils might have been taken from the same bottle, and yet in the field these soils are very different in appearance and in action under the plow. There is also another difference which is not brought out in the table, and that is a difference in the subsoil. The Fancher sandy loam is the same to a depth of 6 to 10 feet, while the San Joaquin red adobe becomes heavier below. One analysis of the second foot is given in the table, showing the heavier subsoil. All of the samples, with one exception, were collected to a depth of 12 inches.

This soil originated in the foothill adobe, and is the finer portions of that soil washed down on the plains, and more thoroughly disintegrated. Undoubtedly, the material comprising the grains is the same, the difference being in the degree of comminution.

Very little of this soil has been irrigated. Almost the entire area is planted to grain crops without irrigation. The heavy character of the soil makes it retentive of moisture, and being close to the foothills the soil receives a greater amount of rainfall than do the soils farther out in the valley, hence the grain production is a little greater per acre than in the sand and sandy loams of the red formation.

Should water ever be obtained for this soil, grapes, and in the protected places citrus fruits, would undoubtedly be profitable.

The soil is high. Standing water is far down, generally 30 feet or more, and there is no danger from alkali. Hardpan underlies large areas of this soil, and whenever it approaches the surface of the ground it offers the most serious obstacle to cultivation.

WHITE FORMATION SOILS.

Underlying the red formation and extending to an unknown depth are sands, sandy loams, and volcanic ash interstratified, and frequently containing thin layers of indurated material. The breaking down of this formation, assisted by the washing and distributing action of the streams, has resulted in the formation of the white soils south of Fresno.

FRESNO SAND.

The Fresno sand covers great areas of land south of Fresno, extending from the Kings River westward to the boundary of the map. This area is cut up by strips and areas of the Fresno sandy loam. The area is a uniform sloping plain, with shallow depressions and drains following the same general trend as the strips of sandy loam. As a rule, the sandy loam strips are lower lying than the sand soils, they having the same relation to the sand soil as do the red sandy loams to the red sand.

Typically, the soil is a loose white sand with no coherence. When

plowed or cultivated the surface breaks up on drying to a deep, loose mulch, as there is not enough clay to bind the grains together. Along Kings River for a distance of 2 or 3 miles from the river the white sand is a little heavier in texture and soft clods form on plowing. These, however, are so soft that they easily break up.

Mechanical analyses are given in the following table:

Mechanical analyses of Fresno sand.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
4874	S. 11, T. 15 S., R. 22 E.	0 to 24 inches...	.82	1.98	14.10	32.70	26.60	16.24	5.10	1.94
4887	S. 27, T. 16 S., R. 22 E.	......do...........	1.21	.90	15.68	30.92	22.30	17.86	8.10	2.91
4875	S. 28, T. 15 S., R. 23 E.	......do...........	.86	......	3.68	11.66	28.36	37.72	14.99	3.16
328	Central Colony	....	1.30	1.56	22.96	26.19	14.96	17.33	12.91	3.60
4884	S. 32, T. 15 S., R. 22 E.	0 to 24 inches...	1.01	......	2.44	14.92	25.88	26.94	23.43	5.62

This soil in mechanical analysis is not far different from the Fresno red sand. The red sand carries a slightly greater amount of clay, but the white sand carries more of the silt and very fine sand, so that the texture alone would indicate a very little difference. In the field, however, there is found considerable difference both in appearance and in working properties. The white sand never becomes compact or hard, does not bake or crack upon drying, and never plows up in clods. The red sand, on the other hand, does all of these. Wherever the two soil types adjoin, the difficulty of distinguishing them becomes great, the two soils grade very gradually from one to the other, there being a zone at least a mile wide possessing the properties more or less of both soils.

These white sands ultimately originated in the rocks of the Sierra Nevada Mountains, but directly they have originated in the white formation underlying the strata of the red formation.

Instead of being entirely sedentary soils from the breaking down of this white formation, the soils have been greatly modified by the flood waters from the foothill streams and from Kings River, and particularly along that river have been modified by the sediment of that stream. Since these soils have been laid down, Kings River has cut a deep channel from the point of exit from the foothills to the trough of the valley, and no longer sweeps over the sand soils. There are well-defined channels, however, which, starting in the immediate vicinity of the river, can be traced nearly across the soils, and moreover the arrangement of the areas of white sandy loam in this sand show evi-

dence of having been caused by stream action. Wind has played a great part in modifying the conditions which existed when Kings River left the upper plains and cut the deep channel which it occupies at the present. Many of the old channels and drains have filled in with drifted sand and at present are but shallow swales in the plain. Large areas of the white sandy loam have been buried by the drifting sands, and their presence is only known from the records of borings.

This soil is typically 6 feet or more deep, there being scarcely an appreciable variation in the texture for the depth. Around the borders of the area and in some low swales a subsoil of white sandy loam is encountered at a depth of 3 to 6 feet.

The drainage of this soil upon the plains is good. It is very porous and permits the ready downward flow of water. In the swales, sinks, and drains very often the ground water approaches the surface and bears enough alkali to cause serious damage to tender crops. A great many of these sinks and drains are filled with water by seepage during the irrigating season, and in the autumn upon turning the water from the canals the water in them promptly lowers and they sometimes dry up completely. The soil in these low places is often seeded to alfalfa where it is not alkaline and where the water never actually comes to the surface. There is more or less uncertainty about such cultivation, since the level of the underground water varies so much during an irrigation season that the alfalfa stands either the chance of being drowned out or of being killed for want of water.

The uplands being well drained are, as a rule, free from harmful quantities of alkali salts within 6 feet of the surface. This is quite contrary to the popular opinion of some areas of the soil. A comparative examination of the alkali and salt maps will show, as a rule, that the white sand is free from harmful quantities of alkali salts. Below the depth of 6 feet, however, in nearly every place examined, this soil carries alkali salts, generally in the white hardpan or in the white sandy loams which underlie the sand. The uplands, however, will never suffer from this alkali if proper precautions are taken. The natural mulch formed by the soil lessens greatly the surface evaporation, and the accumulation of the alkali at the surface is, therefore, not naturally rapid. As long as the subsurface water is not permitted to come close to the surface, there need be little fear of accumulation of alkali. In the swales and drains where the water comes close to the surface alkali salts are likely to accumulate. In a few instances this accumulation has already taken place, but in all of these cases if adequate drainage is supplied this accumulation can be prevented. Wherever the lands have already become alkaline reclamation is possible and easy if an outlet can be found for the water.

A great deal of this sand soil is not irrigated at present, though canals have been dug and over much of it water was once applied.

Years of low water and lawsuits over the right to use water have been the cause of the abandonment of many farms in this soil.

In former years wheat and barley were extensively grown without irrigation. The uncertainty of crops in the dry years and the low yield in normal years have caused a great decrease in this industry, and the area around Caruthers, which once was a great wheat-growing center, is now largely abandoned. This soil is well adapted to some classes of fruit; peaches, nectarines, and apricots do very well. Some of the best peaches seen in the valley were grown in this soil. Wherever it is well drained peaches are a great success, and the reclamation of this arid land and the building up of a great fruit industry waits but the development of an adequate water supply.

FRESNO SANDY LOAM.

This is the soil which is locally known as "white-ash" land. There are great areas of this land southwest and west of Fresno and other areas around Fowler, Selma, and Kingsburg.

The soil lies flat in a perfect position for irrigation in the colony lands south and southwest of Fresno, and was, at the time of the laying out of the colonies, considered the most desirable land for fruit. Around Selma, in the long strips of the soil, it is yet considered a very valuable fruit land. This soil is derived almost entirely from the white loams, sands, and volcanic ash of the white formation. This, from the ashy nature, imparts an ashy feel to the soil and has given rise to the local name. In some places the soil is almost entirely a product from the volcanic ash, and there the ashy nature is very evident. In other places more of the sandy elements are mixed with the soil and the ashy nature in a measure is masked.

The mechanical analyses of this soil follow:

Mechanical analyses of Fresno sandy loam.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
4831	Sec. 3, T. 15 S., R. 19 E...	0 to 12 inches..	2.41	......	0.66	9.98	33.00	33.42	16.25	4.54
4832	Subsoil of 4831	12 to 24 inches.	1.86	......	1.38	9.90	36.78	29.90	16.06	4.15
4833	.....do	24 to 36 inches.	1.15	......	1.48	6.08	40.00	33.40	13.48	3.98
4834	.....do	36 to 48 inches.	.95	......	1.12	10.54	36.82	29.53	15.25	5.19
4878	Sec. 23, T. 16 S., R. 21 E..	0 to 12 inches..	1.74	......	.78	7.55	30.76	34.72	18.69	5.85
4882	Subsoil 4878	48 to 60 inches.	1.84	0.76	.83	3.67	11.39	19.35	49.53	12.07
4683	Sec. 23, T. 15 S., R. 20 E..	0 to 24 inches..	2.22	Tr.	.93	3.51	20.28	27.44	21.63	6.18
3400	4 miles SE. of Fresno ..	0 to 15 inches..	2.65	.27	4.29	10.36	15.88	38.11	22.03	6.70
3398	3 miles S. of Fresno	12 to 24 inches.	1.68	.18	3.76	7.75	16.86	43.93	19.25	6.73
4826	Sec. 28, T. 14 S., R. 20 E..	0 to 12 inches..	1.97	......	1.36	4.92	27.28	25.95	29.78	8.77
4827	Subsoil of 4826..........	12 to 36 inches.	2.11	1.12	1.40	2.26	14.94	39.22	31.85	6.89

The mechanical analyses of this soil show large percentages of fine sand and silt, with about 6 per cent of clay. Such a composition would be interpreted to mean a soil very loamy in character and of great capillary powers. In the field this interpretation is borne out, and in addition to that the soil is found to work well, clods very little, and takes water easily. When puddled, however, water penetrates but slowly, and in such condition when dry the soil forms dense, hard clods.

The subsoil becomes heavier below a depth of 2 feet and, on an average, at a depth of 3 feet bluish clay is encountered. This material is found to be a lime-magnesian hardpan which has been softened by water. In some small areas this material is still hard, but is so disconnected and broken up by the action of water as to be of little obstruction to the growing roots. The analysis of sample 4882 shows the mechanical composition of a sample of the bluish clayey matter. Analyses of the subsoil are given to show the great uniformity of the soil to a depth of 2 feet.

The subsoil clay in the original condition of the soil contained alkali salts, or, in other words, the hardpan is an alkali hardpan.

Irrigation has changed the location of these soluble salts, in some cases washing them down, but more generally causing them to rise. The reasons for and extent of this alkali movement will be discussed in the consideration of the alkali, and the hardpan will be considered later under its proper heading.

Though this was considered very choice soil thirty years ago experience since that time has unquestionably demonstrated that mistakes are very often made in its selection. Nearly the entire area of this soil has to a certain extent suffered from alkali salts, and very much of the land which was once in valuable orchards or vineyards is now seeded down to Bermuda grass for pasturage. The land in good condition was worth $200 an acre. As Bermuda grass pasture it is not worth $25 an acre. This loss of $175 an acre has extended over perhaps a thousand acres of land south of Fresno, and a great deal more land which was originally not so valuable has been damaged. Altogether, upon the area as mapped, there are about 28,500 acres of land which have been so badly damaged by alkali as to be abandoned.

The reclamation of all this alkali land is believed to be possible and profitable. This matter will be discussed in more detail later.

Alluvial Soils.

The term "alluvial" is here used to mean those soils which have been laid down by the rivers in their present condition. No doubt in a strict sense all of the soils are alluvial, since they were laid down by running water, but for the purposes of soil classification the term is confined to those river-bottom soils which are still flooded at times

of very high water, or bear evidences of very recent flooding. Two types of this character of soils were recognized and mapped.

MEADOW.

The meadows, as they have been called, include the bottoms of the Kings River so far as they were mapped. The soil is the sediment dropped by the river waters in flood and in part the material cut down from the banks, sorted over and laid down again.

The soil is a fine-grained micaceous sandy loam, with little true clayey matter and very little coarse sand or gravel. Analyses of three typical samples are shown in the table:

Mechanical analyses of meadow.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4864	Sec. 30, T. 14 S., R. 23 E	0 to 24 inches	4.22	......	Tr.	1.26	10.94	51.70	27.78	3.86
4871	Sec. 24, T. 14 S., R. 23 E	......do	5.09	......	0.82	2.50	10.61	42.50	32.60	5.03
4888	Sec. 9, T. 17 S., R. 22 E.	......do	3.90	......	.10	1.82	8.82	43.74	34.20	7.08

The samples are given in the order of their deposition, Nos. 4864 and 4871 being near Sanger, and No. 4888 being about 4 miles south of Kingsburg. The last sample contains more clay than do the others, as would be expected, since it has been carried farther.

This soil lies low, water is found at an average depth of about 3 feet, and in cases of very high floods most of the land is flooded. A greater part of the area is given over to pasture, but below Sanger there are some fine truck farms, orchards, and large fields in corn.

The native vegetation is rather dense and the expense of clearing the land is great, but the class of crops adapted to the conditions are profitable and warrant the expense. Along the foot of the bluffs in the west side the seepage water from the irrigated plains above has subirrigated a narrow strip of land and in spots alkali has accumulated. This is easily drained away if the proper outlet for the water be supplied.

RIVER WASH.

The area of this soil comprises a narrow draw southwest from Herndon, in the northwest corner of the map. The draw heads in the San Joaquin River at Herndon, and is an old channel of that river which has been abandoned owing to the cutting down of the present channel below the mouth of the old one. The area is so small that there

are no special uses to which it has been put, but it is farmed with the surrounding soils.

The mechanical analysis following shows the soil to be a coarse gravel and sand with not enough clay to render it plastic:

Mechanical analysis of river wash.

No.	Locality.	Depth.	Organic matter, and loss.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4698	Sec. 7, T. 13 S., R. 19 E.	0 to 12 inches ..	1.23	6.50	13.84	10.90	21.14	32.64	10.55	2.92

SOIL MAP.

The areas occupied by the above soils have been indicated by colors upon the map which accompanies this report. Upon the side of the map an average section of the soil to a depth of 6 feet is given.

HARDPAN.

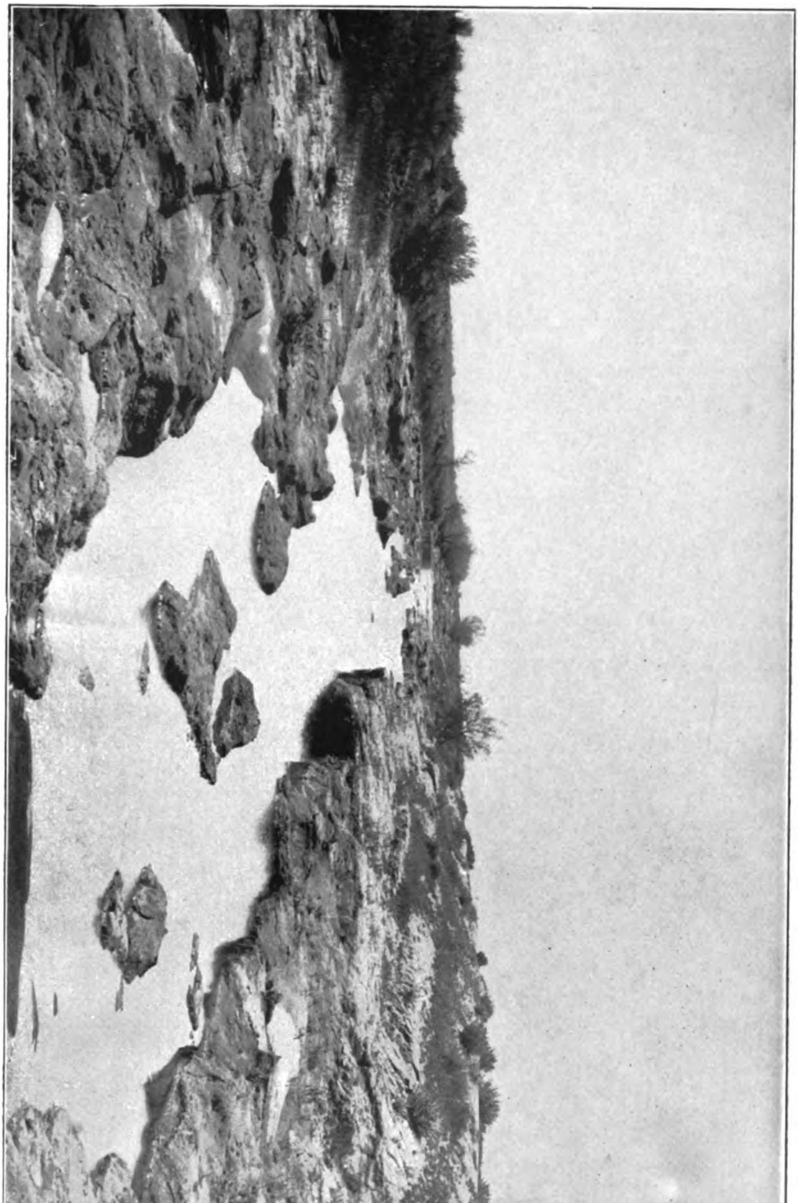
Hardpan is a very prominent feature of the lands in this part of the San Joaquin Valley. The greater part of the land is underlain by hardpan of some kind, though very much of the hardpan is below the zone of rapid root growth, and so does no harm.

Two kinds of hardpan are found, very different in their origin and nature, and at the same time very different in their effect upon the crops grown on the land.

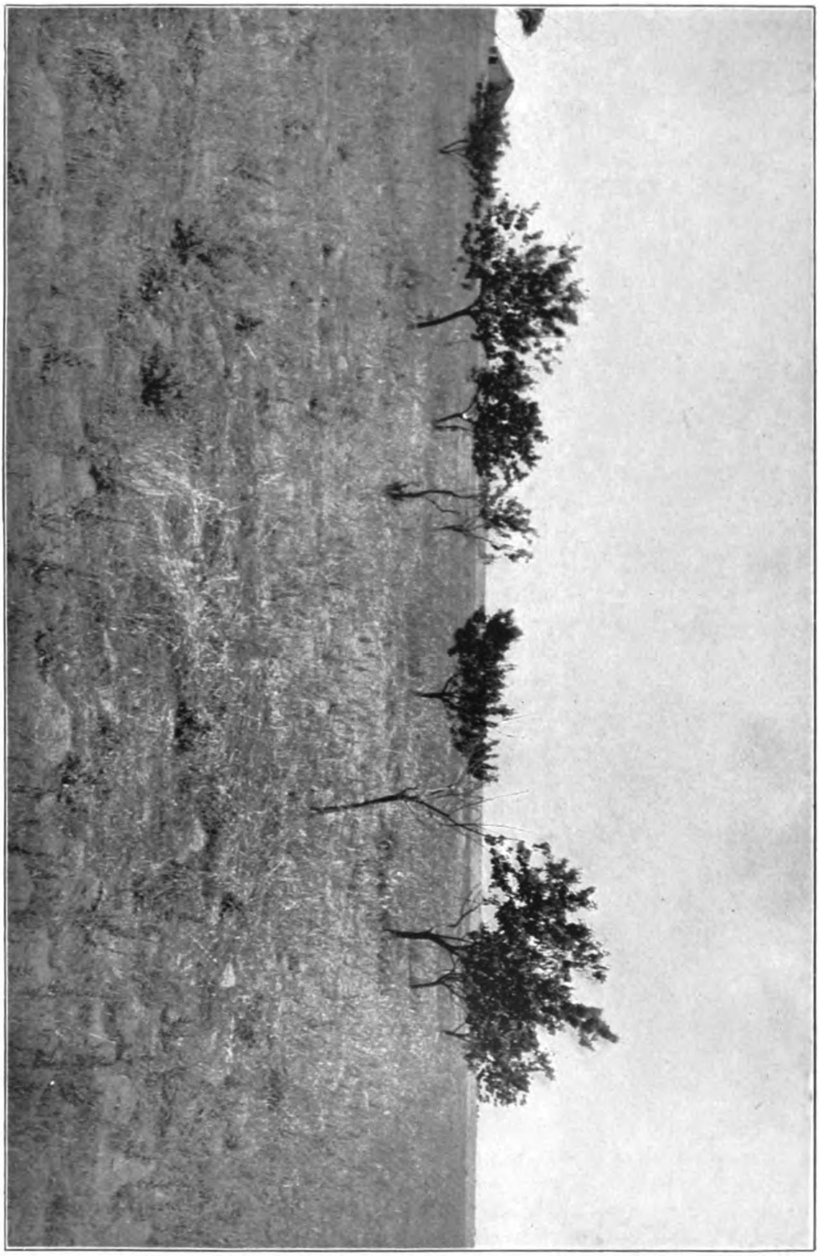
RED HARDPAN.

The most prominent kind of hardpan is a red hardpan. The material is really a red sandstone which lies so close to the surface of the ground as to be called hardpan by the farmers. This material is exposed in the bluffs along the San Joaquin River at Herndon and above. The maximum thickness that has been observed is about 40 feet, though this is not one continuous layer of indurated material. Thin layers of hard sandstone, generally less than a foot thick, alternate with layers of rotten sandstone and loose sand. These layers of hard material are not always continuous, but run gradually into softer material and here and there are broken down altogether.

The cementing material of this hardpan has been found to consist largely of ferric hydrate with some lime carbonate and probably silica. In most cases examined small quantities of lime were extracted from the hardpan. The lime is not considered a necessary feature of the hardpan, since in some samples very little or no lime was found.



RED SANDSTONE HARDPAN IN BOTTOM OF FOWLER SWITCH CANAL.



ABANDONED PEACH ORCHARD ON IRRIGATED LAND WHERE RED HARDPAN IS LESS THAN 2 FEET FROM SURFACE.

Water fails to soften the cementing material. Hot, moderately concentrated hydrochloric acid easily removes the cementing material, causing the hardpan to fall down to sand. Erosion by water is very slow. The bottom of the Fowler's Switch Canal is upon hardpan for long distances; the water of the canal has a high velocity, yet the erosion has not been great.

Wherever this hardpan is less than 3 feet from the surface of the ground the trees or vines which are planted are not able to send their roots as deeply as is necessary for the healthful growth of the plant. Moreover, the hardpan prevents the water from sinking and acts as a shallow evaporating pan in which the rainfall is soon lost into the air by evaporation. Since water does not dissolve the cementing material, the hardpan does not soften after irrigation, hence there is but one remedy—to loosen up the hardpan so that the roots and water can penetrate to lower depths. This loosening can be done by blasting with blasting powder or dynamite. The practice is to dig a pit 3 feet in diameter down to the hardpan, then drill down 2 feet into the hardpan, well tamp a stick or half stick of dynamite, and fire the dynamite before filling the pit. This loosens up the hardpan for a distance of 2 feet around the point at which the plant will be rooted, and gives ample room for the underground development of the roots. Several large vineyards have been treated in this way with apparent success. The hardpan never seems to re-cement after being once loosened up. The cost of this treatment of a vineyard is said to be about $50 per acre. The cost of blasting for orchards would be less, since the number of blasts would be smaller.

The areas of the shallow hardpan, or the areas in which the hardpan is less than 3 feet from the surface of the ground on the average, are shown upon the alkali and hardpan map which accompanies this report. There are about 85,000 acres of land with the hardpan less than 3 feet from the surface. Much of this land, while it is not adapted to fruit growing, raises unirrigated wheat. In fact, the presence of the hardpan, if not extremely shallow, seems to benefit the growth of the wheat, for the hardpan prevents the escape of any of the water from the rainfall by seepage, and thus holds all of the water for the use of the wheat plants. The wheat matures before the hot dry months come on, and thus the plants have advantage of all the moisture before it is evaporated. When the hardpan is less than 18 inches, or 2 feet even, the wheat seems to suffer. This is well shown in the hog-wallow mound country, where wheat can be seen growing upon the tops of the mounds when hardpan is 3 feet down, while in the hollows between the mounds, where the hardpan is a foot or 18 inches down, the soil has dried out and the wheat is dead.

The irregular line drawn across the alkali map shows the southern limit of the red hardpan. All land north of this line can be said to be underlaid at some depth by the red hardpan, and all of the land

south of this line is free from the red hardpan. The areas on which hardpan is less than 3 feet from the surface are shown by shading.

WHITE HARDPAN.

South of the line drawn across the alkali-hardpan map the soil is everywhere underlaid by a white hardpan. This material is a true hardpan, since it has been formed in place by the action of water upon the soils overlying the hardpan. Meteoric waters always carry carbonic acid gas in solution, which dissolves the calcium and magnesium carbonates as bicarbonates from the upper layers of the soil. These bicarbonates are washed down as deep as the rainfall penetrates the soil. Here the aeration of the soil, caused by the temperature changes and changes in barometric pressure, slowly carry away the excess of carbonic acid gas and the lime and magnesium are precipitated as carbonates in a coating around the soil grains. The absorption by the soil grains of carbonic acid gas and the carbonates themselves also assists in the deposition of the lime and magnesium. Small amounts of clay from the upper layers of soil are also washed down, and gradually there is formed at the maximum depth of rainfall penetration a more or less clayey hardpan. In the San Joaquin Valley this mode of hardpan formation is modified by the presence of alkali salts within the soil, and to a certain extent, no doubt, the precipitation of the calcium carbonate was caused by the presence of sodium carbonate and bicarbonate. The presence of the large amounts of dissociated acid ions of the sodium salts in a measure drives back the dissociation of the lime salts, and therefore causes the precipitation of the lime upon the soil grains.

Another point of importance in the formation of the hardpan is that the alkali salts accumulate in the hardpan layer. These alkali salts are washed down by the rain water, but since the greater part of the rainfall in the valley is returned to the air by evaporation it would be natural to suppose that the alkali salts would return to the surface of the ground as the waters come back to the surface by capillary action. There are several reasons why the salts accumulate in the subsoil. First of all, more water moves down through a soil than moves up. This is because a small amount of the water at least escapes downward by seepage. In the San Joaquin Valley this is reduced to a minimum, since the rainfall upon the sandy lands is very largely returned to the surface by evaporation. Plants growing upon the surface of the ground draw water up from below without necessarily absorbing all of the salts which the water contains. There is no question but that part of the evaporation from a soil takes place from the lower depths, the water being carried out and up by gaseous diffusion and by convection caused by changes in temperature and pressure. Again, as the soil waters move down the most concentrated water is in the front of the wave of downward-moving water. The

first films of water largely dissolve the salts and carry them down, while the water which follows carries the more difficultly soluble salts and the absorbed salts. When this water returns to the surface the more dilute solutions are first evaporated, and the more concentrated salts sometimes remain behind. Then again, the salts in solution in the water undoubtedly form double compounds and easily decomposable but scarcely soluble silicates as a film around the soil grains. In this way part of the salt is retained in the lower depths, but upon the drying out of the soil the silicates are decomposed and the alkalis are again liberated. But by far the most important agent in the accumulation of the alkali salts within the subsoil is the absorption of the salts by the surface of the soil grains. Very little is known about the causes or magnitude of these phenomena. The soil grains have the property of concentrating upon their surfaces the salts which are in solution in the soil water. These salts are slowly yielded up to solution in the continuous leaching of a soil, hence when the subsoil is continually washed the alkali salts again appear. They in a way move slower than the water which carries them.

All of these phenomena have an important bearing upon the accumulation of the alkali in the hardpan. No one of the agencies can account for all of the facts observed, hence it must be concluded that all have their bearing upon the movement and retention of the salts.

Since the cementing material of this hardpan is almost entirely lime and magnesium carbonate, water slowly softens the hardpan, and after a few irrigations the hardpan becomes so soft as to permit the roots to penetrate. Thus, though the entire area of land south of the red line across the alkali map is underlaid by hardpan material, there are no areas of any great size where the hardpan is within 3 feet of the surface of the ground, or so close as to harm tree or vine growth. This material, though it is not hard, is often rather impervious to water, and it does much harm in some areas by shutting off rapid drainage into the deeper subsoils. The greatest damage, however, which has been done has been to furnish alkali salts to the soils after irrigation has commenced, for though the tendency of alkali salts is to accumulate in the subsoil in well-drained soils, yet in soils which have been water-logged by irrigation the movement of the salts is toward the surface of the ground.

THE HOG-WALLOW MOUNDS.

Over great areas of land in the San Joaquin Valley, and in a general way throughout California, are found districts in which the ground is covered with small rounded hillocks or mounds. (See fig. 40.) Typically, these mounds are 1 to 3 feet in height and almost round, with a diameter at the base of 10 to 50 feet—on an average about 25 feet. The material of which these mounds is composed is the same as the material of the surrounding soils, except that in gravelly areas very little

gravel is found in the mounds. These mounds occur on several types of soils, but are generally found upon the red soils. Plains and foothills alike are covered with the mounds, and so far as can be learned there is no relation between topography and elevation to the mounds.

Several writers have noted these peculiar mounds and have given theories as to their origin. Whitney, in his Geology of California, volume 1, describes the mounds and calls attention to their resemblance to the mounds produced in eastern forests by the uprooting of large trees by the wind.

Barnes in 1879 (American Naturalist, 1879, p. 565) describes the mounds of San Diego County, and ascribes their formation to the agency of vegetation and wind erosion. At the same time he recognizes that burrowing animals assist in the upbuilding of the mounds.

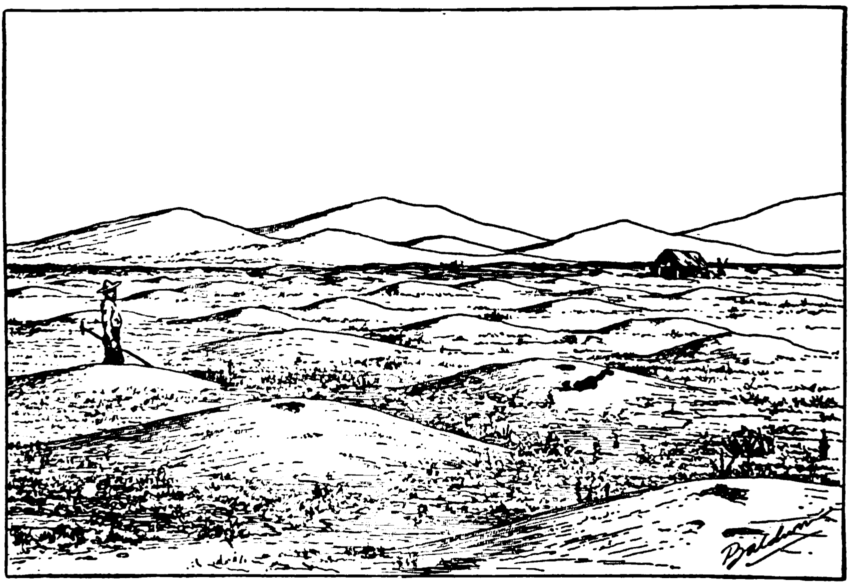


FIG. 40.—Hog-wallow mounds in red hardpan area.

Hilgard, in the Tenth Census report on Cotton Production in California, mentions the hog-wallow lands. He says they are "evidently the result of erosion, but precisely under what condition it is difficult to explain."

Le Conte, in describing the prairie mounds of eastern Oregon (Proc. Calif. Acad. Sci., vol. 5, p. 219), considers the formation of the mounds as due to erosion under peculiar circumstances. The circumstances necessary are a bare country and a drift soil, which is movable above and less movable below. In the erosion, the surface has been removed in part, leaving the top in spots, and the rounded hillocks the result from the spots upon which the vegetation grows, protecting them from further erosion.

The "pimpled prairies" of western Louisiana are very similar in appearance to the hog-wallow mounds. Harris and Veatch (Geological Survey of Louisiana, 1899) give a résumé of the theories for the formation of these mounds. Though in appearance the mounds of the pimpled prairie and the mud lumps of the Mississippi delta resemble the hog-wallow mounds, yet when the two are more nearly compared, certain differences are found to exist. The main difference is that the material composing the mounds is different from the material on which the mounds rest. And in the case of the Louisiana mounds the material has been traced to underlying strata. In the San Joaquin Valley the underlying material to a great depth is often similar to the material forming the mounds, so that the mounds may have been brought up from great depths, without being possible to determine the fact. None of the accepted theories as to the origin of the Louisiana mounds are hardly applicable to California conditions, for the mounds are located upon plains and upon hillsides where the soil is only a few inches in depth.

Turner (17th Ann. U. S. G. S., pt. 1, p. 681), in a brief description of the hog-wallow mounds of Mariposa and Merced counties, calls attention to the similarity between these mounds and the mounds built by the ground squirrels along the Coast Range. He concludes that the mounds were formed by the squirrels in the San Joaquin Valley.

The present writer, after a careful consideration of the possible methods of formation of the mounds, is also of the opinion that the mounds were built by the squirrels or animals of similar habits. Several important points in the characters of the mounds seem never to have been observed, and these are all in a measure important for a complete consideration of the cause of their formation. First of all, though the mounds are not restricted to one type of soils, they are restricted to a class of soils which have the property of hardening on the surface, forming smooth surfaces or hard clods when plowed, and in this way resisting erosion from the surface. This property of the soil enables mounds once thrown up to much longer resist the erosion by rain than would a looser soil, one which does not cement into a hard surface on drying. Good hog-wallow mounds have never been observed in the Fresno white sand or the similar loose soils of the valley, but the Fresno red sand, which has a pronounced tendency to run together and bake, and especially San Joaquin sandy loam, have been frequently observed in hog wallows. Furthermore, the lands in hog-wallow mounds are almost always underlain by hardpan or some hard layer, such as rock. The soil covering the rock or hardpan is not of sufficient depth to suit the tastes of the squirrel, so he throws up a pile under which his dwelling lies, and where the material is hardpan he scratches through the hardpan and brings up soil from below. Squirrel holes through the hardpan have been observed repeatedly immediately under the mounds. It is hardly supposed that one squir-

rel or one generation of squirrels would build one of these mounds, but that the process of formation has been one of ages. The squirrels seem to like to dig holes on elevated portions of ground, such as ditch banks, levees, or even railroad tracks, so instead of building for himself an entirely new mound the tendency has been to start digging at the top of some old mound and thus increase its height. On the foothills, where the soil is thin, the mounds are often higher and are no doubt thrown up to serve as a substitute for a deep soil.

These mounds offer serious obstacles to the cultivation of the land. Before irrigation can be thorough each mound must be leveled down. And even should irrigation not be needed, the farming of dry grain on the mounds is hard on the machinery. Nearly the entire area underlain by the red hardpan is or was covered with these mounds.

THE IRRIGATION WATER AND CANAL SYSTEMS.

The irrigation water of this area is all taken from the Kings River. There are two places from which canals take water direct from the river—at the point of exit from the foothills just northeast of Centerville, and at other places along the sloughs below Kingsburg. The upper canal systems are the most important; very little of the water from the lower canal system is used upon the area of the sheet.

The Kings River at its point of exit from the mountains varies in flow from 30,000 second-feet to a minimum of 250 second-feet. High water occurs from April to July, with the lowest stage during November.

The water of Kings River is very pure. Since it comes from the rain and melted snow almost altogether during the early summer, the water has little opportunity of taking up saline matter in solution. Very few analyses of the water are available for publication. Two analyses by Hilgard, published in the report on cotton production of the Tenth Census, show 7.08 parts mineral matter in solution in June at presumably high water, and 8.62 parts in November at low water. No analyses were made during the summer of 1900, but determinations of the total solids by the electrical bridge, in every case, the water contained less than 8 parts solid matter per 100,000 parts water. This is perhaps as pure a water as could be obtained for irrigation. Rivers in humid climates seldom contain less matter in solution.

The canals which convey the water to the lands of the valley have all been constructed since 1870. The first canals were taken out by private parties near Centerville. These have been extended and enlarged, until the present canal systems taken together would aggregate 150 miles of main canals, with perhaps 2,000 miles of smaller canals and laterals in actual use. Canals run parallel to canals, and water from one canal is carried long distances in laterals, crossing other canals to reach land, which could much more easily be watered from a nearer canal.

The great duplication of canals and laterals has been the result of the slow development of the system. At the present time it is recognized that such a system is very wasteful of water. Changes in the methods of handling the water will be slow in being introduced. These changes are much needed and undoubtedly will come with time. Very little in the way of special effort to remedy the troubles can be seen on the part of the canal owners and managers. If the losses of the present systems could be clearly pointed out, no doubt a much greater effort would be put forth to remedy the conditions.

The canals of the upper systems are: (1) Kings River and Fresno Canal; (2) Fresno Canal; (3) Fowler Switch Canal; (4) Centerville and Kingsburg Canal.

These canals are shown upon the soil and alkali maps. During ordinary seasons all of the canals, except the Fowler Switch Canal, have sufficient water to irrigate the land covered by them, but during dry seasons the greater part of the water goes directly to the country around Fresno through the two canals first named. As a result, this country is very often supplied with an excess of water, while other districts in the valley are suffering for want of water. The amount of water which passes by Centerville in the Kings River, if uniformly distributed over the valley, if properly handled and protected from losses by seepage, would cover a much greater area than is at present irrigated. There are large areas of valuable fruit land which await a supply of water, and which would be profitable investments if water could be furnished them.

One of the greatest sources of loss of water is from seepage through the bottoms and sides of the canals. From the mechanical analyses of the soils which have been given, it will be seen that most of the soils are very porous. Canals, constantly running ditches, and laterals therefore lose quantities of water which could otherwise be applied to the useful purpose of irrigating dry lands. No new data upon the losses from the canals are at hand, but tables published by Grunsky in Water Supply and Irrigation Papers No. 18 show that the losses are great. In a distance of 20 miles the Kings River and Fresno Canal lost 64 cubic feet per second, or a little more than 3 cubic feet per mile of the canal. This would be equivalent to 0.9 feet in depth per day of twenty-four hours if the canal has a wet perimeter of 60 feet. Of the 23.5 miles of the Fresno Canal measured, the loss was 104.5 cubic feet per second, or 4.4 cubic feet per second per mile. This would amount to a loss of 1.2 feet in depth per day of twenty-four hours. The upper 12.5 miles of the canal loses 8.5 cubic feet per second per mile, or a depth of 2.3 feet per day. The Centerville and Kingsburg Canal loses 138.3 cubic feet per second in the first 7 miles, or at the rate of 19.7 cubic feet per second per mile. This would equal an average depth of 5.3 feet. The seventh mile of this canal loses 52 cubic feet per second, or 14 feet in depth.

The loss by evaporation is negligible when compared with these losses by seepage. The maximum daily average evaporation would never equal 1 inch.

These great losses have caused the level of subsurface water to raise from a depth of 100 feet or more to the present level of 10 feet. The amount of water lost would irrigate large areas of land, and, should this leakage be stopped, the ground water over much of the area would lower sufficiently to permit the reclamation of the alkali lands without underdrainage.

THE UNDERGROUND WATER.

When irrigation first commenced in the country around Fresno ground water was first found at a depth of from 70 to 150 feet. At present water can be obtained anywhere in the irrigated portion at from 10 to 20 feet, while over the country immediately around Fresno, during the irrigating season, water can be found at from 3 to 10 feet.

This great filling up of the subsoil with water points toward great waste of water in some manner. All water which passes below the depth of root penetration is lost to all good at the point applied, and is a serious menace to land lying lower. There are two ways in which water is wasted in irrigation: First, by seepage and evaporation from the canal; and, second, by excessive irrigation.

Both of these losses are common in the Fresno area, and in the earlier days of irrigation, no doubt, were much more prominent than at present. The first applications of water to the new lands were largely taken up by animal burrows and underground channels in the hardpan. Sinks were formed, and for days at a time water would be poured into holes. In many places the ground would sink perceptibly after the first few irrigations. Cases have been known when water to a depth of 10 or 12 feet has been used in one irrigation. All of this excessive water has gone to raise the level of standing water in the subsoil, and the present losses are just about sufficient to keep the level in its present position.

Quite marked variations occur at the present time in the level of the water. As soon as the irrigating ditches are filled in the spring the level of the water in the wells begins to rise. Immediately the water is turned out of the ditches and canal the level begins to lower. There is a prompt drop as soon as the water is turned out. The drop is as much as 8 or 10 feet in some of the wells of the district, and as far as can be found the average drop south of Fresno would be 4 or 5 feet. This indicates a rapid natural drainage.

The character of this underground water is uniformly good where it is not concentrated by evaporation. In the areas of red soil, that is, the soils from the red formation, the wells are generally good; the water never carries more than 25 parts of solid matter in 100,000. In the white soils, however, the well waters often carry a higher quantity

of total solids in solution. These wells vary from 25 to 100 parts of salt per 100,000 parts of water, though very few of the wells examined go over 50 parts. Black alkali or sodium carbonate is not a conspicuous salt in the well waters. Very few of the well waters carry more than 10 parts of sodium carbonate per 100,000. Most of the waters, however, carry bicarbonates in solution. From the average of a few determinations the wells can be said to carry, on an average, about 20 parts bicarbonates, calculated as sodium bicarbonate.

When the surface of the ground water is high ponds are formed in many of the sinks and draws in the white soil. Here the evaporation causes the waters to concentrate, and in part drives away the carbon dioxide from a sodium bicarbonate in the water. Thus, the pond waters are very often concentrated and contain much black alkali. The sodium carbonate acting upon the vegetation around the ponds dissolve organic matter and gives the water a brown or black color. Ponds have been examined which carry as much as 3 per cent sodium carbonates and 2.6 per cent sodium bicarbonates, with a total salt content of about 8 per cent. The water which enters these ponds, however, is not concentrated; there is no reason to believe that the water is any more concentrated than the well waters. The examination of a few samples of fresh seepage water showed practically the same salt content as the well waters.

ALKALI IN THE SOILS.

As has been stated, a careful examination was made of the formations from which the soils were derived, to determine, if possible, the origin of the alkali in the soils. The red formation, or those deposits derived from the basaltic rocks, in all places examined failed to show any large quantities of alkali salts; neither in the bluffs exposed in the open wells nor in the soil were great quantities of alkali salts found. A few spots of alkali were noticed in the bottom of the old stream channels east from Fresno, and one area of alkali land was found in the long tongue of Fancher loam running southwest from Fresno. This area is surrounded by alkali soils of the white formation, and the salts are derived from the white formations immediately underlying the red soils rather than from the red soils themselves.

The white formation from which the white soils were derived was found generally to be impregnated with alkali salts. In the bluffs along the San Joaquin and Kings rivers salts were found crystallized out upon the sides of the banks, alkaline waters were found seeping out from the foot of the bluffs, and in the wells in the soils the water carried larger quantities of alkali salts than did the well waters from the red formation. The soils were found everywhere to be more or less alkaline.

Upon the breaking down of the white formations to soil, the alkali salts which are present remain in the soil in part. The rainfall

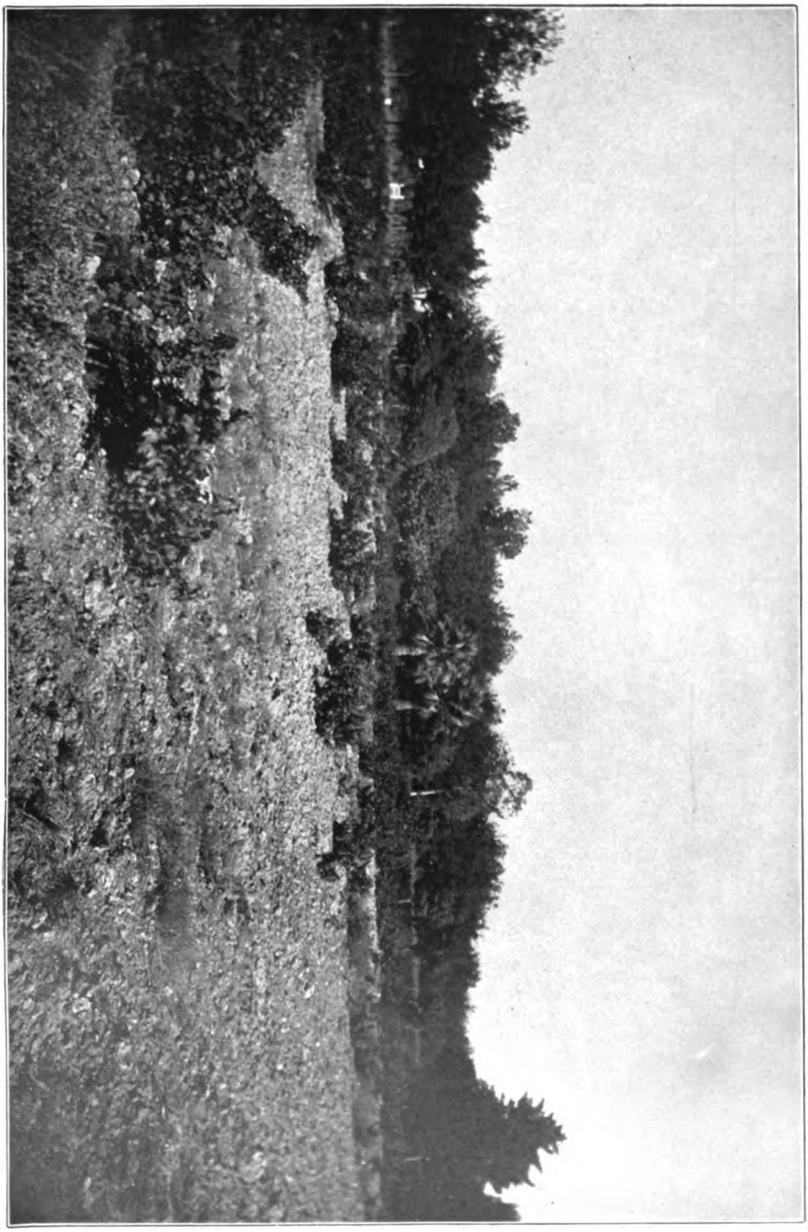
is not sufficient to wash the soils free from alkali to any great depth. There is, however, sufficient of rain to wash the upper parts of the soil so that the alkali in the virgin condition of the soil very seldom shows upon the surface. It is never safe to judge from the surface conditions alone whether a soil contains alkali or not, nor is an examination to a depth of 2 or 3 feet sufficient. In the examination made around Fresno, borings were made to a depth of 6 feet in nearly all cases, and occasionally the soils were examined to a depth of 12 or 15 feet. An average boring in land which has been very little disturbed by irrigation shows the alkali of the soils to be buried at a depth of from 3 to 8 feet. In the sandy loams where the rainfall penetrates but a short distance the depth to the zone of accumulation of the alkali is generally about 3 to 4 feet. In the sands the rainfall penetrates deeper, and here the alkali is found deeper. In all cases the alkali is in greatest quantity in the blue lime-magnesium hardpan. This is to be expected, since the hardpan is formed by the same agents which cause the accumulation of the alkali in a zone beneath the surface. This hardpan can therefore be called an alkali hardpan. The following tables show the results of several borings in the soils as nearly unaffected by irrigation and cultivation as was possible to find:

Alkali in Fresno sand, unirrigated.

No. 164, S. 35, T. 14 S., R. 20 E.				No. 853, S. 35, T. 15 S., R. 21 E.			
Depth.	Soil.	Total alkali.	Na_2CO_3.	Depth.	Soil.	Total alkali.	Na_2CO_3.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
0 to 1 foot	Sand	0.06	0.00	0 to 1 foot	Sand	0.06	0.00
1 to 2 feet	do	.10	Tr.	1 to 2 feet	do		
2 to 3 feet	do	.24	.07	2 to 3 feet	do	.06	0.00
3 to 4 feet	do	.29	.10	3 to 4 feet	do	.11	0.00
4 to 5 feet	Soft hardpan	.11	.16	4 to 5 feet	do	.11	Tr.
5 to 6 feet	do	.09	.06	5 to 6 feet	Soft hardpan	.12	.03
				6 to 7 feet	do	.11	.03
				7 to 8 feet	do	.09	.02
				8 to 9 feet	Sand	.08	Tr.
				9 to 10 feet	do	.05	Tr.

Alkali in Fresno sandy loam, unirrigated.

No. 177, S. 35, T. 14 S., R. 20 E.				No. 286, S. 30, T. 14 S., R. 19 E.			
Depth.	Soil.	Total alkali.	Na_2CO_3.	Depth.	Soil.	Total alkali.	Na_2CO_3.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
0 to 1 foot	Sandy loam	0.09	0.00	0 to 1 foot	Sandy loam	0.11	0.00
1 to 2 feet	do	.15	Tr.	1 to 2 feet	do	.14	.10
2 to 3 feet	do	.16	.10	2 to 3 feet	do	.14	.10
3 to 4 feet	Soft hardpan	.30	.14	3 to 4 feet	do	.12	.12
4 to 5 feet	do	.32	.00	4 to 5 feet	Soft hardpan	.11	.14
5 to 6 feet	do	.16	.06				



FIRST APPEARANCE OF ALKALI IN VINEYARD.

Thus, it is possible to heavily flood a soil, have good underdrainage, and yet get rid of the alkali salts very slowly. The downward movement of the salts, therefore, is very slow, and is not directly dependent upon the amount of water run through the soil.

This fact, however, points to a method of removing the salts by flooding which is efficacious, and that is frequent flooding with small quantities of water rather than by one or a few heavy floodings. By frequent floodings with an inch or more of water the downward movements are largely capillary, and the amount of salt removed by capillary movements is much greater than where the movement is gravitational alone.

(3) *Movement by surface tension.*—When water moves by surface tension the film around the grains moves. As soon as the gravity water has drained away the movements become entirely by surface tension, for changes in temperature or concentration of the solution change the tension of the water films and starts a capillary movement toward the point where the evaporation takes place or away from the place of higher temperature. But when the water moves by capillary action it is the water in the smaller spaces that moves, and not the water which was in the larger noncapillary spaces. Therefore, the water which was drawn back into the capillary spaces and carried the alkali salts as it flowed down into the soil, starts upward and carries with it the salts which are in solution. The evaporation of an inch of water from the surface of the ground accumulates on the surface all alkali salts which were contained in that inch of water, while on the other hand the same volume of water leached down through the soil would perhaps only wash the salt out of a few of the larger soil spaces. From this it will be seen that the tendency of the alkali salts under irrigation is to move upward more rapidly than to move downward. Were the tendency and the rapidity of movement the same in both directions, the rise of alkali salts would never be possible if a little more water was added to the surface of the ground than evaporates each year from the surface. In the Fresno area we know that in many cases a great deal more water has been added to the surface than could possibly have been evaporated from the surface; in other words, more water flowed down than has flowed up; and yet the alkali salts have come up. This is readily understood when we consider that the downward movement is through the larger, noncapillary, spaces, while the upward movement is through the smaller, the capillary, spaces.

This goes to show that surface tension or capillary attraction, as it is often known, is the most important agent in the movement of the alkali salts toward the surface of the ground. Therefore, a soil which would permit the most rapid movements would be the most likely to accumulate alkali salts upon the surface of the ground. If two soils with different capillary powers were placed side by side, with the level

of standing water the same, the soil which raised the water to the surface the more rapidly would the sooner accumulate an alkali crust.

South of Fresno there are examples of such soils—the Fresno white sand (loose and coarse grained) and the Fresno sandy loam (fine grained and compact). The rate of capillary rise and the height to which water will rise in the sandy loam are both much greater than in the sand; consequently the sandy loam will accumulate an alkali crust much more rapidly than the sand. Such has been found to be the case throughout the area. The sandy loam or white-ash land is nearly always troubled with alkali, and is very often heavily crusted with alkali salts, while the sand is very seldom sufficiently charged with alkali as to be worthless. It is true that the alkali salts are more abundant under the sandy loam, and that it is accumulated in a zone nearer the surface than in the sand, but in areas side by side where the conditions could not have been far different originally, the sand is found free from alkali in the surface, while the sandy loam has an accumulation of alkali at the surface. The washing of salts out of the open porous soils and the accumulation in the heavier soils is very well illustrated in the alkali lands in T. 15 and 16 S., R., 19 E. Here the original conditions are very little affected by irrigation. The draws and low places are generally of the sandy loam, while the ridges between the draws and the higher plains are of sand. The sand soils are free from alkali salts in the upper 5 or 6 feet, while the sandy loams are invariably alkaline, and even when the soils are side by side at the same level the alkali is found in much greater quantity in the heavier soil. Here we have a beautiful example of the Briggs movement of capillary water from a light soil to a heavier soil, the moving water in this case taking with it the alkali salts. Some of the causes for the movement of alkali salts in soils have been shown; the special causes for their accumulation in the Fresno soils now remain to be considered.

When the colony lands south and southwest of Fresno were first settled, very little of the land was alkaline on the surface. After a few years' irrigation and when the subsurface water had been raised high enough to permit constant upward movement by capillarity, the alkali salts began to accumulate. In the soils of most rapid capillary movement the damage occurred most rapidly, and this sometimes with frequent and copious irrigation from the surface. After this accumulation has gone on for a while the greater part of the alkali salts is found at or near the surface of the ground. The same accumulation is observed in the unirrigated soils where the subsurface water is close enough to the surface to permit continuous capillary movement upward. Such soils are said to be subirrigated. When, however, the subsurface water is down so far that there is no capillary movement continuously upward, or when the rainfall does not penetrate

to the subsurface water, the alkali salts do not accumulate at the surface, but in a zone beneath the soil, as has been previously described.

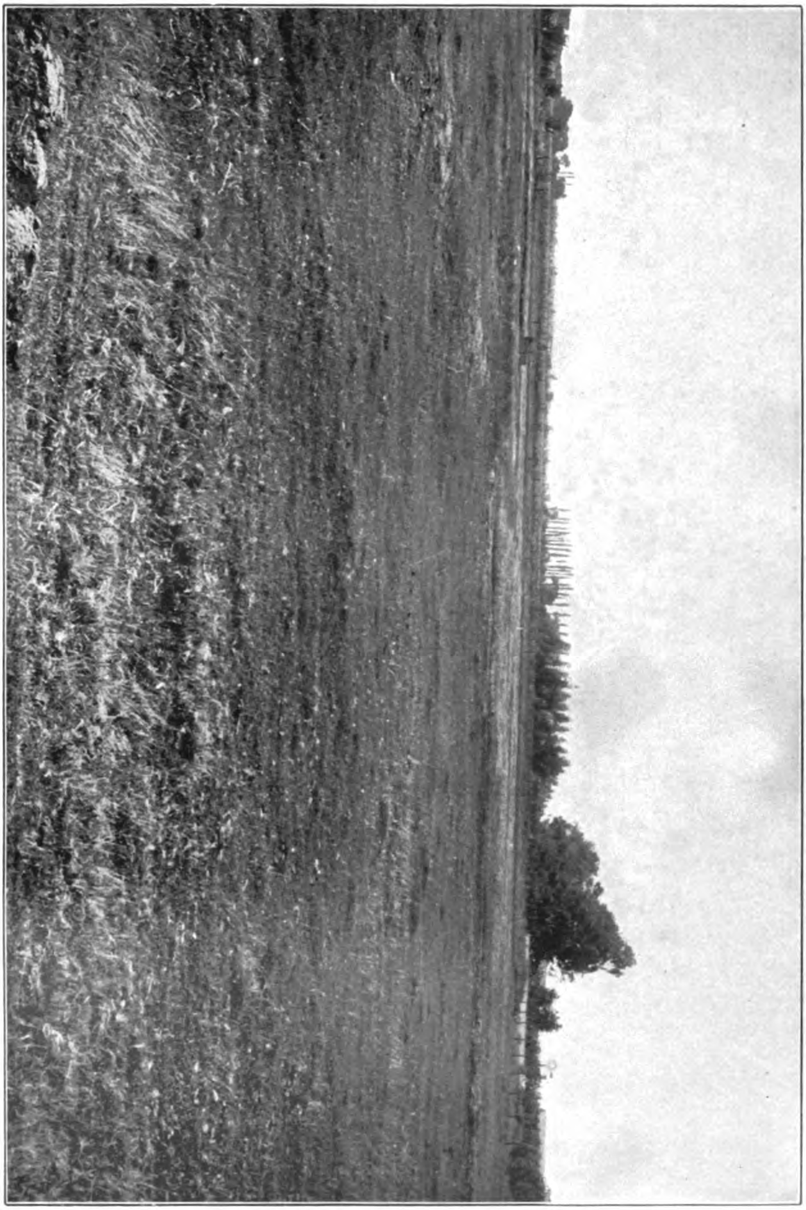
Therefore, if the subsurface water had never been allowed to approach the surface of the ground, as was done in the colonies south of Fresno, the alkali salts would never have been accumulated at the surface. This is seen in the two long strips of Fresno sandy loam east of Selma. Here the water surface never comes higher than 6 to 8 feet from the surface of the ground. Capillary movements through 8 feet of soil are not rapid; hence the salts have very slowly moved upward, or else have not moved at all. The subsoil, however, contains alkali, perhaps as much as did the colony lands south of Fresno, and if ever the level of standing water around Selma rises to within 3 or 4 feet of the surface a great part of the now valuable fruit land will become alkaline. On the strip of land south of Selma the water surface is already near the surface of the ground during part of the year and the alkali has accumulated so that nothing but salt grass will grow.

CHEMICAL COMPOSITION OF THE ALKALI.

A large number of chemical analyses of the alkali salts from the Fresno area have been made in the Division of Soils. A general discussion of the results is given by Cameron.[1] The accepted classification of the alkali salts has been heretofore black alkali when the salts contained sodium carbonate, and white alkali when the salts did not contain sodium carbonate. Cameron has considered a new classification, in which the types are defined by the principal salts found in the crusts. This classification is certainly a more rational one and deserving of further study. The general type of the alkali salts in this district is called the Fresno type by Cameron, and he considers the predominating salts to be sodium or potassium chloride reacting with calcium or magnesium carbonate. As accessory salts, we have small quantities of sulphates and occasionally traces of phosphates.

The analyses are given in the tables on pages 373 and 374. For convenience, the analyses which showed no sodium carbonate are given in one table, while those analyses which showed sodium carbonate are given in a second table.

[1] See paper by Cameron in this report.



LAND TOO ALKALINE FOR FRUIT CROPS, SEEDED TO BERMUDA GRASS FOR PASTURAGE.

Chemical analyses of alkali salts containing no sodium carbonate.

Constituent.	4872. Sec. 19, T. 14 S., R. 22 E., crust.	4841. Sec. 25, T. 14 S., R. 18 E., 0 to 12 inches.	4871. Sec. 7, T. 14 S., R. 23 E., 0 to 24 inches.	4681. Sec. 22, T. 14 S., R. 19 E., 0 to 12 inches.	4835. Sec. 22, T. 14 S., R. 19 E., 0 to 12 inches.	4676. Sec. 20, T. 14 S., R. 20 E.	4682.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ca	18.71	12.59	17.25	1.60	9.51	15.96	2.76
Mg	8.21	5.26	5.59	.74	3.30	9.33	.56
Na	5.34	15.56	7.93	31.11	21.28	....	33.33
K	.92	1.15	3.50	2.63	1.86	9.33	1.55
SO_4	1.00	1.60	2.33	25.84	4.54	8.66	7.56
Cl	64.60	60.40	55.71	33.39	54.55	56.66	53.00
CO_3	....	....	....	....	....	Tr.	....
HCO_3	1.31	3.44	7.69	4.69	4.96	....	1.24
PO_4	....	....	....	....	....	....	....
$CaSO_4$	1.38	2.28	3.27	5.43	6.40	12.00	9.40
$CaCl_2$	50.64	34.61	44.75	....	21.08	34.66	....
$MgSO_4$	....	....	....	3.66	....	....	1.14
$MgCl_2$	32.75	20.49	21.91	....	12.81	35.99	1.34
K_2SO_4	....	....	....	....	....	....	....
KCl	1.74	2.05	6.53	4.97	3.51	17.34	2.96
Na_2SO_4	....	....	....	28.25	....	....	....
NaCl	12.82	35.77	13.05	51.23	49.39	....	83.46
Na_2CO_3	....	....	....	....	....	....	....
$NaHCO_3$	1.77	4.79	10.49	6.46	6.81	....	1.70
PO_4	....	....	....	....	....	....	....
Per cent soluble	4.61	.87	.86	3.50	.97	.30	8.23

Chemical analyses of alkali salts containing sodium carbonate.

Constituent.	4689. Sec. 2, T. 15 S., R. 19 E., 0 to 12 inches.	4670. Sec. 9, T. 15 S., R. 20 E.	4831. Sec. 3, T. 15 S., R. 19 E., 0 to 12 inches.	4690. Sec. 7, T. 15 S., R. 19 E., 0 to 1 inch.	4668. S. 22, T. 14 S., R. 20 E.	4684. Sec. 26, T. 14 S., R. 20 E., 0 to ½ inch.	4839. Sec. 21, T. 14 S., R. 19 E., 0 to 1 inch.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ca	Tr.	1.81	2.31	Tr.	3.65	....	1.15
Mg	Tr.	1.64	Tr.	Tr.	1.99	Tr.	Tr.
Na	33.78	19.34	32.41	35.27	23.80	35.26	36.16
K	1.86	19.43	1.85	1.01	10.86	.68	.83
SO_4	11.97	12.09	5.55	24.03	10.20	12.31	18.91
Cl	29.92	41.28	36.49	27.11	39.64	22.40	24.50
CO_3	3.19	4.40	5.00	4.99	9.87	10.58	14.90
HCO_3	19.28	....	16.29	7.59	....	18.67	3.55
PO_4	Tr.	....	....	Tr.	....	.10	....
$CaSO_4$	....	6.13	8.13	....	12.36	....	3.91
$CaCl_2$	....	....	....	....	....	....	....
$MgSO_4$	....	8.12	....	....	1.82	....	....
$MgCl_2$	....	....	....	....	6.46	....	....
K_2SO_4	....	2.83	....	....	....	....	....
KCl	3.46	35.05	3.51	1.93	20.65	1.30	1.56
Na_2SO_4	17.69	....	....	35.57	....	18.23	23.91
NaCl	46.68	40.59	57.31	43.23	41.30	35.93	39.42
Na_2CO_3	5.72	7.77	8.68	8.82	17.42	18.72	26.34
$NaHCO_3$	26.45	....	22.37	10.45	....	25.72	4.86
PO_4	....	....	....	....	....	.10	....
Per cent soluble	1.50	2.32	1.08	8.30	2.41	24.00	9.19

Chemical analyses of alkali salts containing sodium carbonate—Continued.

Constituent.	4688. Sec. 36, T. 14 S., R. 19 E., 0 to ¼ inch.	4829. Sec. 31, T. 14 S., R. 20 E., 0 to 12 inches.	4680. Sec. 30, T. 14 S., R. 20 E., 0 to ¼ inch.	4677. Sec. 28, T. 14 S., R. 20 E., crust.	4877. Sec. 8, T. 17 S., R. 21 E., 0 to 12 inches.	4886. Sec. 17, T. 17 S., R. 21 E., crust.	4686. Sec. 19, T. 14 S., R. 20 E., 0 to ¼ inch.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ca	Tr.	3.52	Tr.	2.55	0.48	0.20	Tr.
Mg	....	Tr.	Tr.	.50	.16	....	Tr.
Na	36.46	28.74	36.23	31.08	33.77	34.90	36.08
K	.98	.59	.73	5.96	1.81	1.15	.41
SO_4	8.22	3.81	8.93	17.84	5.44	17.09	5.17
Cl	24.97	4.99	15.58	21.86	8.06	2.50	5.81
CO_3	15.26	16.71	20.26	20.31	22.63	23.56	26.30
HCO_3	13.61	41.64	17.81	....	27.65	20.60	26.01
PO_4	.50	....	.46	....	....	....	.27
$CaSO_4$	....	5.28	....	8.32	1.60	.67	....
$CaCl_2$	....	*a* 8.21	....	....	....	....	....
$MgSO_4$	....	....	....	2.46	.75	....	....
$MgCl_2$	....	....	....	....	....	....	....
K_2SO_4	....	....	....	13.28	....	....	....
KCl	1.86	1.17	1.37	....	3.47	2.19	.79
Na_2SO_4	12.16	....	13.20	3.96	5.50	24.69	7.65
NaCl	39.73	7.04	24.64	36.04	10.72	2.39	8.95
Na_2CO_3	27.02	29.62	35.81	35.90	39.96	41.67	46.51
$NaHCO_3$	18.73	48.68	24.52	....	38.00	28.39	35.83
PO_4	.50	....	.46	....	....	....	.27
Per cent soluble salts	6.76	.68	9.92	3.99	3.75	28.22	26.07

Constituent.	4862. Sec. 34, T. 13 S., R. 23 E., crust.	4679. Sec. 22, T. 14 S., R. 20 E., 0 to ¼ inch.	4669. Sec. 34, T. 14 S., R. 20 E., crust.	4888. Sec. 9, T. 17 S., R. 22 E., 0 to 24 inches.	4678. Sec. 18, T. 14 S., R. 20 E., crust.	4889. Sec. 11, T. 17 S., R. 21 E., crust.	Standard solution.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ca	4.58	Tr.	1.75	3.01	0.48	0.04	0.10
Mg	Tr.	Tr.	.42	....	.21	....	....
Na	31.46	37.26	30.66	34.19	35.03	41.85	34.24
K	.76	1.12	9.87	.63	7.85	1.26	5.83
SO_4	5.34	2.31	9.80	7.24	7.13	2.35	18.92
Cl	3.05	11.99	15.75	2.41	5.82	1.15	29.75
CO_3	30.84	28.71	31.71	33.85	43.48	52.79	11.59
HCO_3	23.97	18.44	....	18.66	....	.56	....
PO_4	....	.17	....	....	....	....	....
$CaSO_4$	7.48	....	5.88	10.28	1.62	.10	.32
$CaCl_2$	*b* 6.11	....	....	....	....	....	....
$MgSO_4$	....	....	2.03	....	1.00	....	....
$MgCl_2$	....	....	....	....	....	....	....
K_2SO_4	....	....	7.35	....	9.43	....	....
KCl	1.37	2.13	12.67	1.15	6.89	2.41	9.77
Na_2SO_4	....	3.42	....	....	....	3.36	27.74
NaCl	3.97	18.12	16.03	3.04	4.20	....	41.63
Na_2CO_3	48.09	50.76	56.06	59.85	76.88	93.35	20.53
$NaHCO_3$	39.96	25.40	....	25.68	....	.77	....
PO_4	....	.17	....	....	....	....	....
Per cent soluble salts	1.31	16.42	2.86	1.91	5.81	54.24	....

a $Ca(HCO_3)_2$. *b* $CaCO_3$.

The alkali salts normally contain sodium carbonate, but in special cases, which cover but a small part of the total area of alkali lands, sodium carbonate is wanting. The analyses given in the first table show the composition of the soluble portions of a number of such soils. All of the samples, except 4681, instead of showing sodium carbonate, show large quantities of chlorine, which must be largely combined with lime and magnesium as chlorides. The accumulation of calcium and magnesium chlorides is the result of the action of sodium chloride upon calcium carbonate. Both being in solution at the same time, calcium chloride must exist in the solution. Calcium chloride is a salt which moves very rapidly in a soil. Some experiments made with various chlorides (Yearbook, 1898, p. 498) showed that calcium chloride could be washed from a soil in one-half the time required to leach the same quantity of sodium chloride. As the water moves through the soil the tendency is for the calcium chloride to move more rapidly than the other salts, and hence it accumulates in the place when these waters have evaporated. The extent of these white alkali spots is not large.

Sample 4681 was collected from a spot which had been treated with gypsum; therefore the large amount of sulphates found in the salts.

The second table contains analyses of samples of alkali crusts which contained sodium carbonate. The analyses are arranged according to the content of sodium carbonate, which varies from nearly 6 per cent to over 93 per cent of the soluble portion of the soil. The principal constituents of the soil are seen to be chlorides and carbonates with bicarbonates. Lime and magnesium are low, so that the salts are largely salts of sodium and potassium. Potassium forms an average of 5 per cent of the soluble matter within the soil. Sulphuric acid is always present, but rather variable, and on the average constitutes 6 per cent of the total alkali salts. The relation between the carbonates and bicarbonates varies greatly as found in the field. The drying out of the samples in transit to the laboratory so changes the relative proportion of these two salts that a laboratory examination gives no idea of the relations which exist in the undisturbed soil. Field examinations were made in the many samples for the relation between carbonates and bicarbonates, and even here the relative proportion is found to vary greatly. Carbonates of sodium and potassium have been generally considered the most harmful salts found in the alkali of the soils. Researches in this laboratory show that the bicarbonates are themselves not as harmful as the carbonates, so that a simple statement of the carbonates and bicarbonates from the laboratory determinations does not suffice for a discussion of the field conditions.

These alkali crusts containing sodium carbonates occupy almost the entire area of the alkali lands. (See fig. 41.) White alkali lands are found in very small spots only. Gypsum has long been known as

a chemical correction for black alkali. Hilgard has recommended its use, and wherever it has been tried the reclamation has been a success, if enough gypsum were applied. Gypsum, it must be remembered, does not remove the black alkali from the ground, but simply changes it over into white alkali, which is a less harmful form; so if there is already an excess of white alkali in the soil the application of gypsum is of little value, since even the changing of the black to the white only serves to add to the total percentage of white alkali. But wherever the total percentage of white alkali is small gypsum will greatly improve the land.

RECLAMATION OF ALKALI LANDS.

The areas of the various grades of alkali soils, as determined from the map areas, are as follows:

Areas of the different alkali soils.

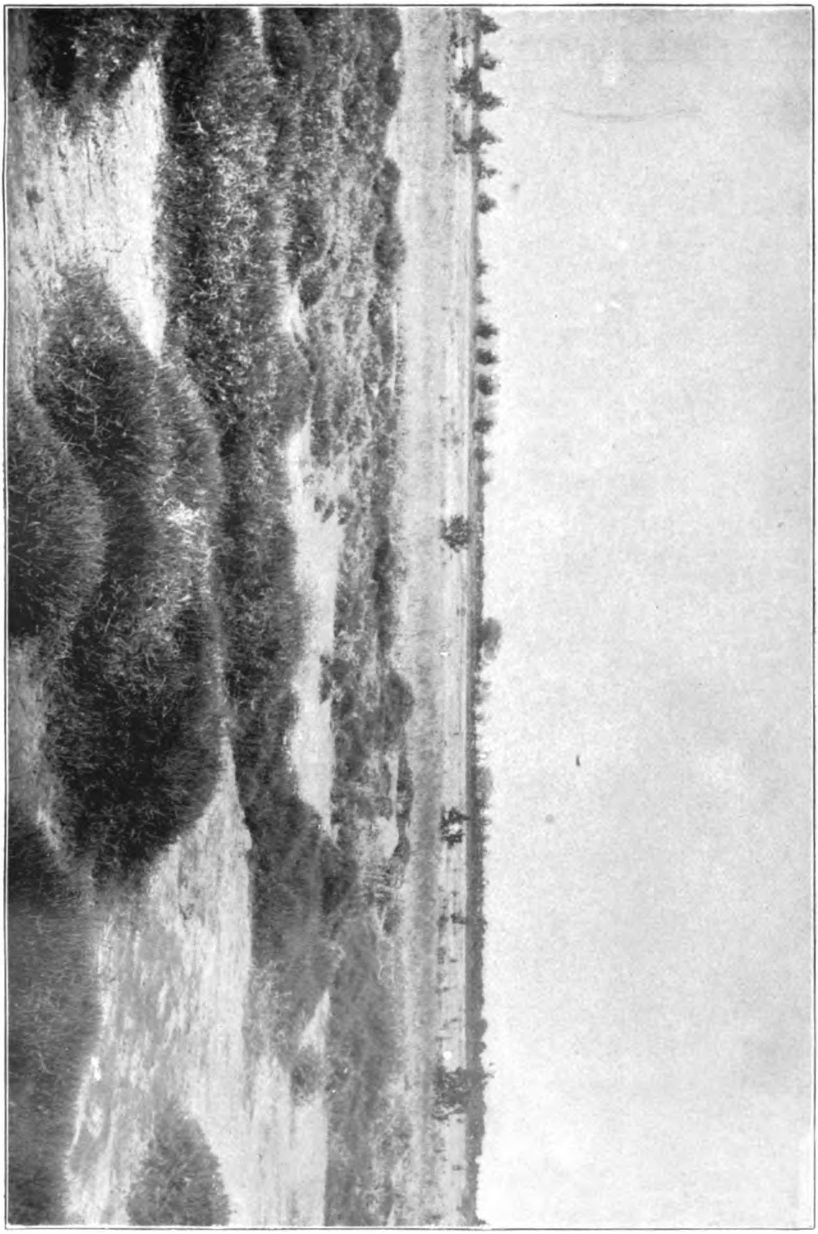
Grades of alkali soils.	Acres.	Per cent.
0 to 0.2 per cent alkali	336,300	83.8
0.2 to 0.4 per cent alkali	26,300	6.6
0.4 to 0.6 per cent alkali	10,150	2.5
Over 0.6 per cent alkali	28,500	7.
Total area	401,250	

These percentages of alkali are based upon a column of soil 5 feet deep, as determined by the electrical method for the determination of salt in soils as used in this Division.

Upon the first grade of land, with 0 to 0.2 per cent total alkali, all classes of plants will grow.

Upon the second grade of land, 0.2 to 0.4 per cent of alkali, all but the most sensitive plants will grow, but near the higher limit of the percentage of alkali all classes of plants except the truly alkali-resistant plants show signs of distress, and if the conditions remain unchanged the death of the plants will result. Alfalfa, if well started, grows on this class of land, but seed are difficult to germinate. Fruit trees show the presence of alkali by dropping the fruit before ripening. Grapes will grow, but not with the vigor of the plants on good land. Pomegranates, pears, date palms, all do well. Beets, onions, and asparagus also are unaffected by the presence of the alkali.

The third grade of land, 0.4 to 0.6 per cent alkali, contains a little too much salt for the common crops. Alfalfa will seldom grow and can never be seeded on the land. Fruit trees all suffer or are killed, with the exception of pomegranates and date palms. Only the truly alkali-resistant plants do well, such as beets, onions, asparagus, date palms, Bermuda grass, Johnson grass. The land is worthless for ordinary fruit farming, and is in the Fresno country either allowed to lay as waste land or is seeded down to Bermuda grass for pasturage.



ALKALI LAND TOO STRONG FOR FRUIT CROPS OR BERMUDA GRASS, WITH VOLUNTEER GROWTH OF SALT GRASS.

Lands once exceedingly fertile. Fresno sandy loam.

The fourth grade of land is that with more than 0.6 per cent of alkali, and is practically worthless for general farming or fruit raising. Salt grasses, Australian saltbush, and a number of wild or native saltbushes will grow, but, aside from pasturing, these lands are not used. Date palms would grow upon these lands, and in some cases sorghum and sugar beets could be grown, but these have not been tried to any great extent.

There are two problems which confront the irrigator farmer: First, to prevent lands becoming alkaline; second, to reclaim lands which

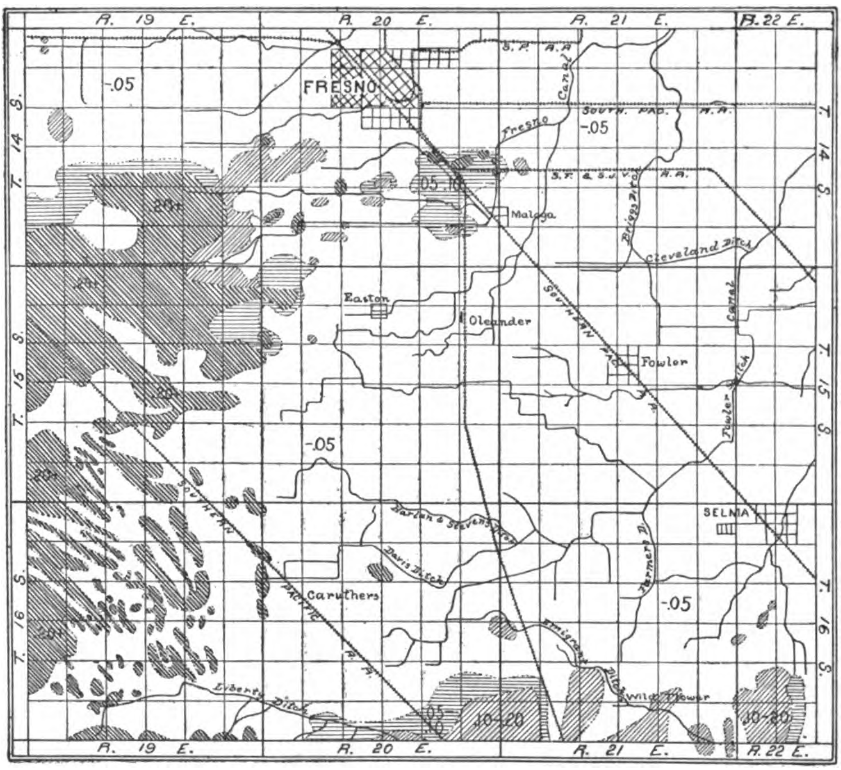


Fig. 41.—Black alkali lands of Fresno sheet, showing lands less than 0.05 per cent, from 0.05 to 0.10 per cent, from 0.10 to 0.20 per cent, and over 0.20 per cent sodium carbonate.

have already become alkaline. These two problems, while they are closely related, will be discussed separately.

PREVENTION OF THE RISE OF ALKALI.

In the discussion of the formation of the hardpan and the alkali in the soils the reasons for the movements of the alkali have been shown. The main factor in the rise of the alkali is the capillary rise of the water and the evaporation of this water at the surface. If the capillary rise of the water is slowed down or prevented and the evaporation at the surface is reduced to a minimum, the accumulation

of the alkali salts at the surface will be greatly retarded and often prevented entirely.

There are two ways of lessening the upward movements of the water: First, by lowering the level of standing water; second, by cultivating the soil and breaking up the capillary spaces into large noncapillary openings.

If the level of standing water is down 5 or 6 feet, the upward movement is slow and very little can be done toward further lowering the level of the water; but if the level of the water is within 3 feet of the surface or nearer, underdrains should be dug to lower the level of the standing water. Except in the case of lands which are entirely free from alkali, the level of standing water should never be allowed to come closer than 3 feet from the surface.

Deep cultivation of the soil breaks up the fine capillary spaces and cuts off the upward movements of the water. At the same time the cultivation dries out a surface layer, which prevents the upward movement also, since the capillary movement through a dry soil is much slower than through one slightly moist. Continued shallow cultivation forms this dust mulch and prevents surface evaporation.

Mulching either with a dust mulch or with straw, leaves, or manure all aid in preventing evaporation, and the use of these means of lessening the loss of water from the surface of the soil is to be strongly recommended. An orchard was studied near Selma where stable manure was used as a mulch. Very little of the alkali had approached the surface, and no trees had been killed, although there was enough alkali in the subsoil to entirely ruin the orchard if it were allowed to rise to the surface. Orchards near by and in apparently exactly similar conditions originally, and on which no mulch was used, were found to be suffering from alkali.

RECLAMATION OF LANDS ALREADY ALKALINE.

Alkali lands which grow only salt grass and salt weeds are worth very little when compared with lands free from alkali. Ten dollars an acre is the average price fixed on alkali lands, though the land is not worth half so much. Land free from alkali and with water is worth at least $100 an acre, and if in fruit it is worth $200 to $500 per acre, and will pay good interest on that amount.

Land which will only grow certain crops is partly damaged and would not be considered as valuable as land free from alkali, therefore all of the classes of alkali land are not so valuable as the land free from alkali.

The researches of this Division have shown that the reclamation of alkali lands is a practical business proposition. The increase in value of the lands after reclamation in nearly all cases is greater than the cost of reclamation. The land when once reclaimed is known to be rich, strong land, in better condition than the land originally free from the salts. Part of the alkali is plant food in an available form,

and hence the presence of small quantities of alkali always stimulate plant growth.

There are a number of ways in which alkali lands can be reclaimed, all of them deserving of use in special cases—(1) growing of alkali-resisting plants; (2) chemical correction for black alkali; (3) cultivation and flooding; (4) underdrainage.

(1) *Growing of alkali-resisting plants.*—The growing of alkali-resistant plants of some sort is nearly always possible, for there is very little land which would be farmed which is too strongly impregnated with alkali for some kind of growth. For the strongest alkali soils, the wild saltbushes, salt grass, and Australian saltbush are available. Such lands can only be used as pasture. Lands less strongly impregnated will frequently grow sorghum or beets, which withstand considerable alkali. The growth of these plants alone is a very slow and uncertain method of reclamation, but if this method is taken in conjunction with heavy flooding and thorough cultivation complete reclamation is possible.

(2) *Chemical correction for black alkali.*—Gypsum is a chemical correction for black alkali. Well-drained and aerated soil is necessary before gypsum is efficient. The action of gypsum is to react upon the sodium carbonate with the formation of sodium sulphate. If there is 0.1 per cent of sodium carbonate within the soil, 3¼ tons of gypsum are required to neutralize the carbonate, and at the present market prices the gypsum would cost $19.50 per acre, and this would reclaim only the first foot. Should the reclamation of the entire 5 feet of surface soil be desired, the cost would be $97.50 per acre for the gypsum alone. And after all this expense the land would still contain white alkali, perhaps in quantity sufficient to do harm. There are very few areas on the Fresno sheet which have an excess of black alkali and do not at the same time have an excess of white alkali. Gypsum applied to such areas is largely wasted. It is true that gypsum assists in changing the physical conditions of a heavy soil so that water flows through it more easily, but at Fresno there is very little heavy soil. Gypsum can not be recommended as of general use in reclaiming the alkali lands of the Fresno sheet. The use of gypsum where there is but a small quantity of alkali present is often of value, but at the present price of the material it is not economical.

(3) *Cultivation and flooding.*—Whenever the level of standing water is down so far as to prevent rapid capillary movements to the surface of the ground, cultivation and flooding offer one of the most ready means of reclaiming alkali lands.

Deep cultivation breaks up the root holes and cavities which are followed by water in leaching downward through the soil. In this way a heavy flooding carries downward into the subsoil much more alkali than would be carried if the land were irrigated before plowing. If some alkali-resistant plant which can be cultivated is then planted and properly attended to, frequently cultivated and irrigated, and

this kept up for two or three years, much will be done toward the reclamation of the land; and if a proper kind of alkali-resisting plant is selected and the product handled intelligently the land will pay for the care in attending to it, so that the increase in value due to reclamation is clear profit.

This all presupposes a good and rapid underdrainage, that is, some place to which the alkali can go. If such is not present naturally, the only remedy is underdrainage.

(4) *Underdrainage.*—Well-drained lands never become alkaline. Therefore if lands have become alkaline it is evident that the drainage has been poor.

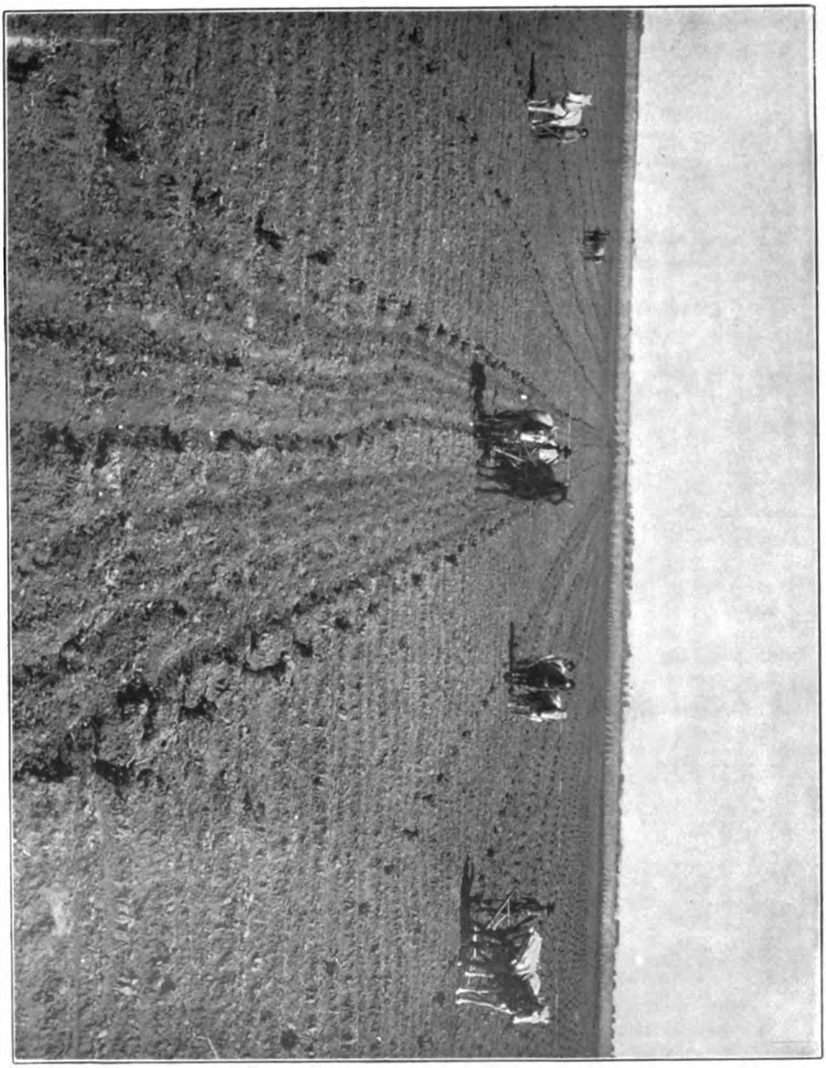
With good underdrainage the alkali salts are washed out and away into the stream channels, and are never of harm to the land from which they came. There are several ways of underdraining land, all of which are applicable to conditions under irrigation. A discussion of the subject of farm drainage is found in Farmer's Bulletin No. 40, of this Department.

To sum up the matter of reclamation of alkali lands: Two requisites must be had before attempting reclamation. They are a supply of water with which to irrigate and good underdrainage to the land. See that both are right, then plow deep, irrigate heavily, and plant an alkali-resisting crop. Sugar beets and sorghum are both good. Cultivate frequently to a depth of 4 inches, and irrigate often. Keep this up for three years, and then try alfalfa. If alfalfa can be gotten to stand well, the land is nearly reclaimed.

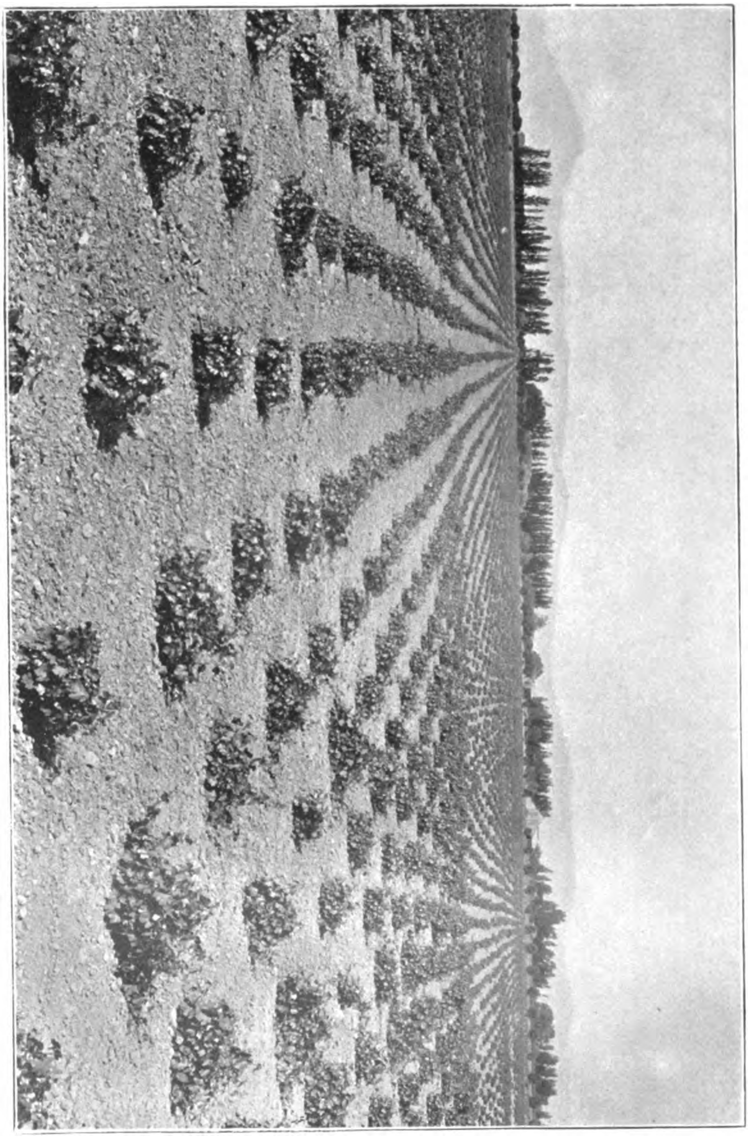
AGRICULTURE ABOUT FRESNO.

The agricultural lands about Fresno are divided into two classes—the irrigated and nonirrigated lands. These divisions are not merely accidental, but in most cases are decided by some peculiarity of the land itself, either in its location or inherent properties or by the amount of water in the streams. For example, nearly all of the San Joaquin sandy loam is dry farmed to wheat and barley, because here, as a rule, the hardpan comes so close to the surface as to exclude any deep rooting plant or tree, and in like manner the sandy land near Caruthers is also dry farmed or else left idle, the limiting cause here being location, rather than any inherent property of the soil, all of the water of the river being diverted for irrigation before reaching this point; so that in general it may be stated that the great bodies of land that are now unirrigated are so because of the difficulty or impracticability of bringing them under irrigation, and that they are liable to thus remain indefinitely, or until the present methods of obtaining and applying water undergo a radical change.

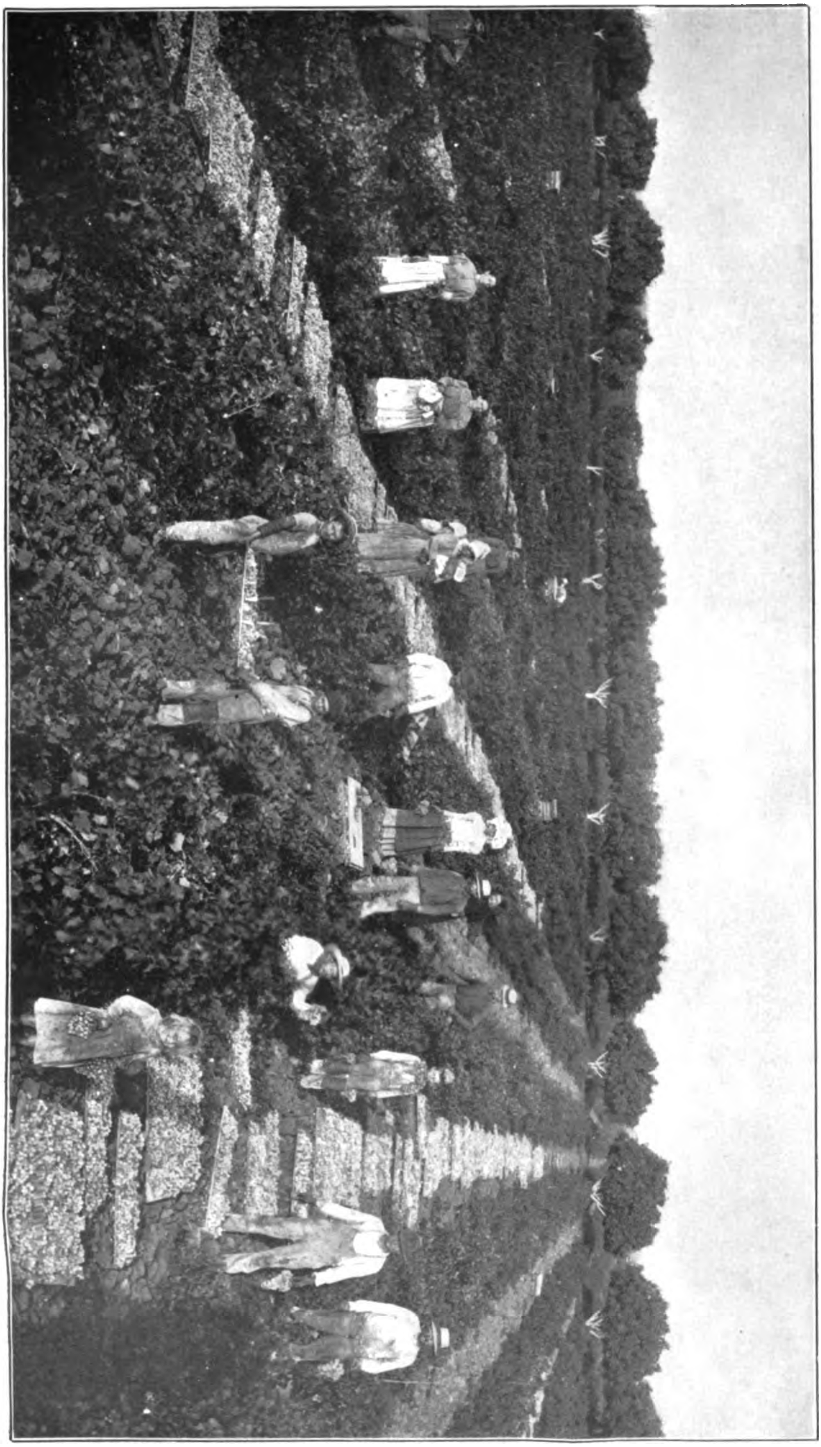
The area mapped about Fresno comprises about 401,250 acres; of this amount about one-third is now irrigated and planted to fruit trees and vineyards, one-third dry farmed to wheat and barley, and the remaining one-third includes the land sown to alfalfa; the alkaline



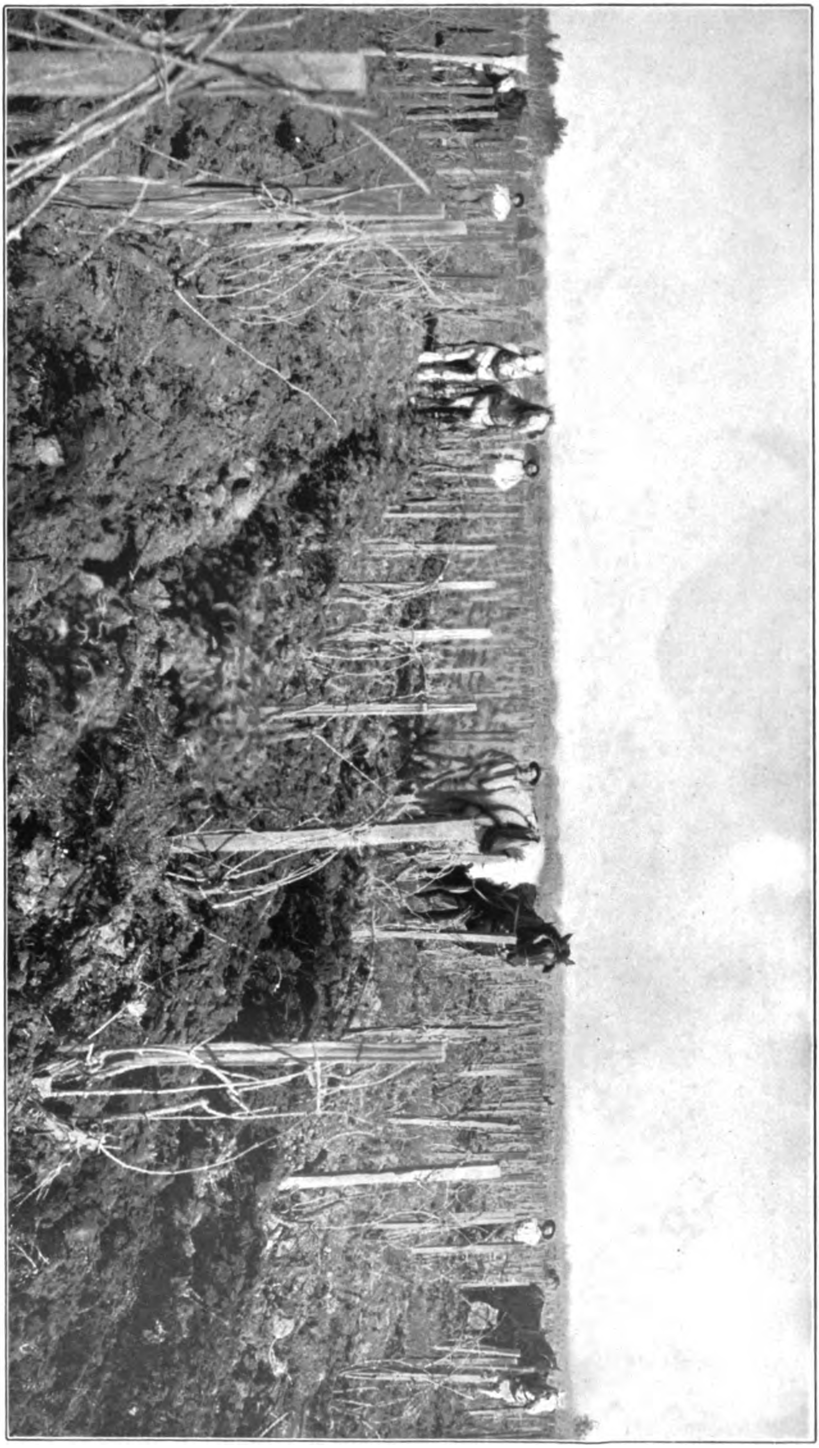
RAISIN GRAPES, PRUNED AND RECEIVING WINTER CULTIVATION.



RAISIN GRAPES, IN EARLY SUMMER.



RAISIN GRAPES, HARVEST TIME.



WINE AND SEEDLESS RAISIN GRAPES, SHOWING PRUNING AND WINTER CULTIVATION.

lands, and the land which, on account of its sandy nature and the scant rainfall, is left idle. A part of the alkali land comes under the irrigation ditches, so about two-fifths of the area is irrigated, while the remainder is dependent solely upon the rainfall.

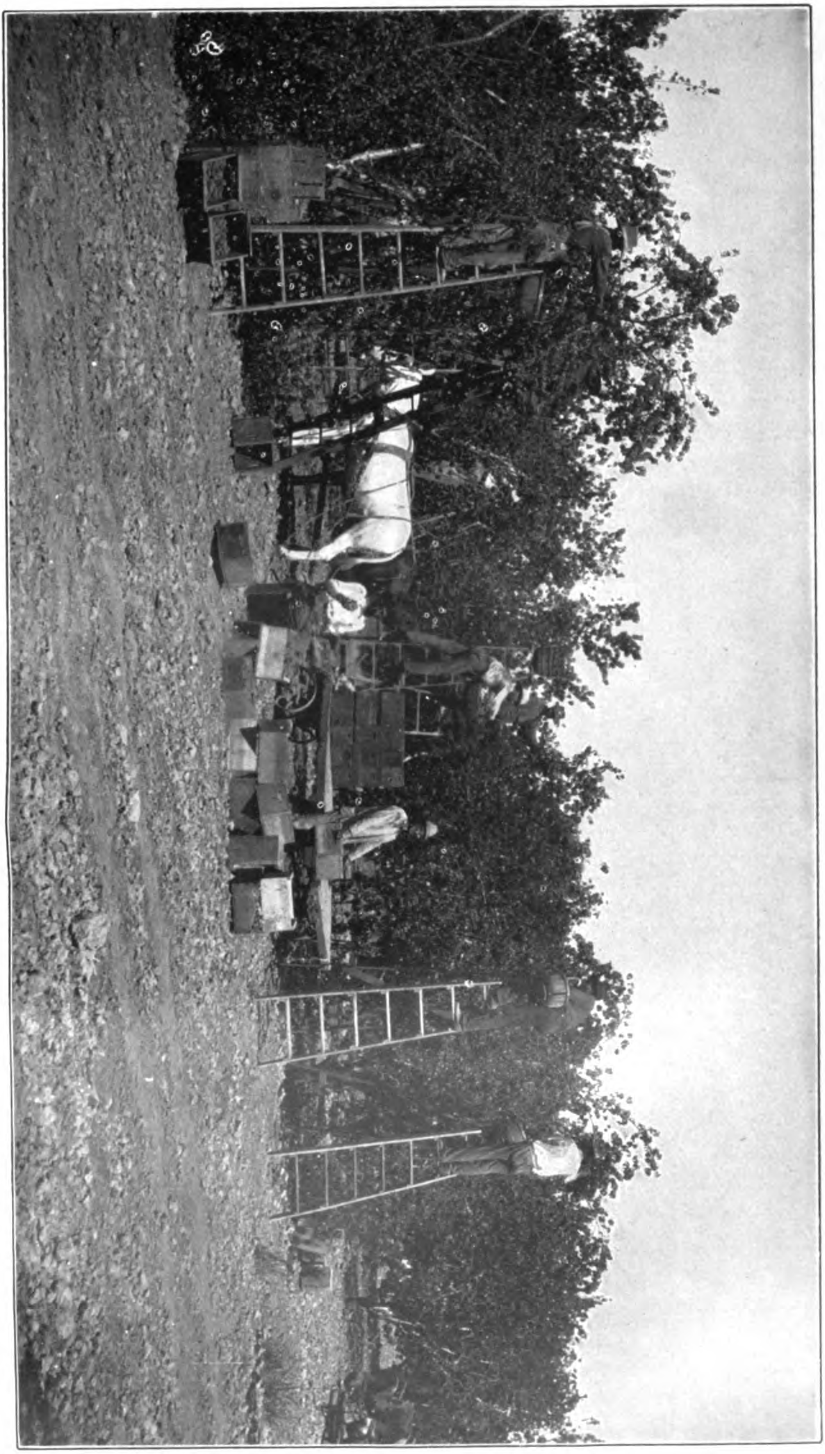
All the irrigation of this country is of very recent date. Thirty years ago the first ditch was built to divert water from Kings River to irrigate a small tract near Centerville, and from this first effort, which was considered highly experimental, has grown an agricultural community based wholly upon irrigation which counts its assets in the millions. Heading the list of irrigated crops in importance and value are the grapes, the products of which are two of the principal sources of the revenue of the county.

The grapevines are started from slips or cuttings 18 inches or 2 feet long, which are pieces of the trimmings of the old vines. These are placed very close together in a trench, with one end protruding a few inches above the ground, and irrigated copiously for one year until they have developed a few branches and a root system. They are then taken up and planted in the vineyards, the distance apart varying with the kind of grape and the judgment of the planter, from 6 feet apart each way to 10 or 12 feet, the average distance being 8 by 10 feet. The vineyards are then carefully cultivated and pruned, producing their first crop the third or fourth year. The pruning of the vines is of great importance, the object being to gain the maximum yield for the space occupied by the undivided vines and at the same time permit of cultivation between them. With this end in view all varieties are found to occupy as small space as possible. The Muscat, Malaga, Seedless Sultana, and Thompson Seedless are raisin grapes, of which the two first named are the most important, only small plats of the seedless grapes being grown. The Muscat and Malaga vines are each winter pruned back to a stump or very short trunk about a foot high, and as the vines get older these trunks increase in size, often being a foot or more in diameter. The cultivation is so managed that it is finished before the new vines grow to such length as to interfere with the cultivation; in other words, the grapes are annually "laid by," just as the Eastern farmer lays by his corn. The cultivators used are usually drawn by 2 horses and have a great number of small teeth which tend to form a mulch and at the same time destroy any growing weeds. The methods of cultivation for these varieties apply to the others also, the principal difference in the culture being in the methods of pruning. The Thompson Seedless, Seedless Sultana, and most of the wine grapes are either staked, that is, a stake driven down by the plant for a support and the vine tied to it, or they are pruned with a large stem 4 or 5 feet high, which supports its own weight of vines and fruit. In either case the result is the same, the object being to raise the grape-producing branches above the level they would occupy if pruned closer, as in the case of the Muscats. In ordinary seasons the farmer

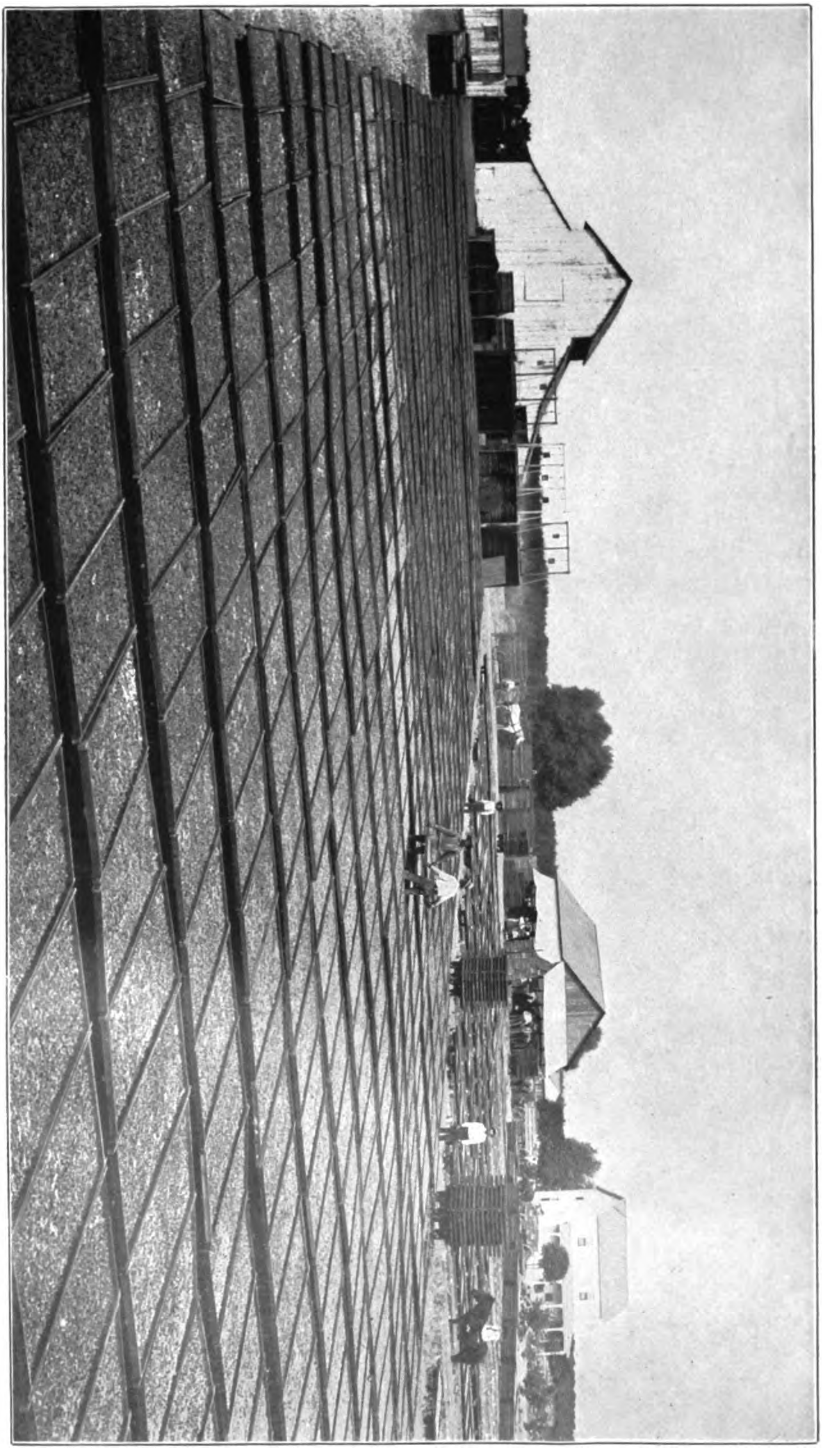
is not troubled by weeds after his vines are laid by, but when late spring rains occur and destroy the mulch that has been prepared and again wets the surface much added expense must be charged to cultivation. In some limited localities much harm may be anticipated from the spread of Johnson grass. This is a stiff, coarse grass which grows from 3 to 6 feet tall and spreads very rapidly, both from the seed and underground runners or roots, which push out laterally in every direction. When once it gains a foothold it is wellnigh impossible to destroy it without at the same time destroying the crop which it menaces. It attacks all irrigated plats that come within its range, so that it not only is a menace to grape culture, but to all agricultural industries where irrigation is practiced. Its favorite haunts seem to be along the ditch bank, where its ripening seed fall into the running water and are carried to the fields below. This is a matter which should command the immediate and urgent attention of every irrigator in Fresno County, as even now large vineyards and orchards, sometimes of a hundred or more acres in extent, have been practically abandoned on account of this grass alone, and the damage in the future promises to be much greater. Since the raisin and wine industries are greater than any others here, it would seem that the grape grower should be the one to take the initiative in the matter and seek to devise methods of relief from this pest.

The grapes begin to ripen about the 1st of August, and soon after the wineries, of which there are a great number in the county, are running at full capacity, buying the grapes from the growers and reducing them to wine. About the 10th of August the raisin grapes are ripe and picking begins. They are picked, placed on trays to dry in the sun, and after drying placed in boxes that hold about 100 pounds and "sweated." They are now taken to the packing houses, where they are sorted, the Muscat bunches being packed on the stems, while the others are stemmed and some seeded, and packed in boxes of 20 pounds each ready for shipment. The price to the grower the past season was on an average of about 4 cents per pound for dry raisins. An average production per acre is 1 ton, so that the gross receipts per acre from the raisin crop are $80. To this must be added the receipts from the second crop, which ripens later and is sold to the wineries at $10 per ton for the fresh grapes. Chinamen and other cheap laborers are generally employed in the culture and harvesting; so it can readily be seen that the grape growers' net returns or profits are great. But it has not always been thus; for a few years ago only wine grapes repaid in any great measure the efforts of the grower. But within the last two years the growers have organized what is known as the Raisin Growers' Association, which has practically doubled the profits of all raisin growers.

Not all of the soils of the irrigated lands will produce grapes in paying quantities, the most notable example being the Fresno sand. On this soil peaches are planted, so that this crop has come to be the



PICKING PEACHES FOR DRYING.



DRYING PEACHES.

second in importance to the grape. The Fresno sand seems to be especially adapted for peach growing, and for the first few years requires no fertilization, but after this the yield begins to lessen and fertilizers are needed. The peaches are planted about 30 feet apart, and cultivated and irrigated after the manner of all the orchards of this region. There are a great many differences of opinion as to the best methods of pruning, the matter being decided by the man in charge of the orchard. When the peaches are ripe they are either cut in halves and dried in the sun on trays or carted to the cannery to be canned in tin cans. The profits from a peach orchard in full bearing are about the same as from a vineyard, and since the greater part of the land now without water is the Fresno sand, the peach industry may be expected to grow as the development of water increases.

There are a great many other varieties of fruit grown in this irrigated area about Fresno. In fact, it is one vast orchard and vineyard. The two mentioned crops, however, are the principal ones. Pear trees are grown quite extensively on land that has become too badly alkaline for the less resistant crops. Fig trees are usually planted along the edges of vineyards, bordering the roads and drives. These are the variety of figs which produce a fruit whose seeds are not fertile and which are called mule figs. Attempts to grow the Smyrna fig at the Fanches Creek nursery have now met with success, however, and the past season a crop was matured with the aid of the fig insects, a few of which were imported from Smyrna by the Department of Agriculture and the insects grown and attended to, just as they are in Smyrna, under the direction of the Department.

Along the base of the foothills near Centerville is a belt of land where citrous fruits may be grown. As yet, however, the industry has been only small, but in the near future a great many acres will be planted to oranges and lemons, since it has already been demonstrated that they are a commercial success.

Prunes, plums, apricots, and the smaller varieties of fruits, such as blackberries, strawberries, etc., are successfully grown, but of these the apricot only is of commercial importance. These are dried or canned, and in some localities are quite extensively grown.

Several hundred acres of irrigated land in the Kings River bottom southeast of Sanger are devoted to truck crops, some of which are shipped to the San Francisco market and the remainder sold in the markets of Fresno.

The alfalfa that is grown is either in small patches on the fruit farms to furnish feed for the family cow, or else is on land which, because of the accumulation of alkali, is unfit for the culture of fruits. In some cases these latter areas are large, but because of the alkalinity of the soils upon which it is grown the fields are usually spotted and the crops are in no case as large as in other regions where alfalfa is grown from choice rather than necessity. The foxtail grass

which covers this whole area greatly injures the first crops of alfalfa, and in some cases the entire crop is burned to destroy the seed of this grass. After the first cutting is disposed of no further trouble occurs from this grass until the next year's first crop.

In the low, swampy Fresno slough country quite a little dairying industry has been built up in the past few years, but its influence is limited as yet, so the principal crops of the irrigated region are the fruits, since other crops are grown only where fruits are for some reason excluded. When irrigation first began the ground water was from 50 to 100 feet below the surface over all this irrigated area, but now the whole country is so filled with water that some of the deep rooted crops require no irrigation, but obtain their water wholly by subirrigation, in some places the water coming within 3 or 4 feet of the surface.

On the lands uninfluenced by irrigation waters only wheat, barley, and rye are grown, and these are grown with only the slight rainfall of the region. The common practice now is to summer fallow the land and in this way hasten nitrification and also carry over some of the moisture of one year which, added to that of the actual growing season, is sufficient to mature the crop.

Wheat is now sown during the fall and winter months, usually after the first rains, and completes its growth by the latter part of May. The last two months of its growth are entirely without rain, its only supply of water being the moisture stored in the soil. Because of the long period of no rainfall including, as it does, the time of the ripening of the wheat, peculiar methods of harvesting are employed. The old method was to head the grain and then thresh it, but now, large combined harvesters are being used in the larger tracts with great success. These require from 24 to 36 horses to draw them, and cut, thrash, and sack the grain ready for shipment. From this machine the sacks are dumped three in a place and afterwards are collected and drawn to the large warehouses, where it is stored awaiting shipment. For the drawing of this wheat, 10 horses, with 2 wagons, one a trailer, are employed. In this way one driver controls the whole and thus cuts the labor expense. Fifteen bushels per acre is now about the average yield for wheat, and from this yield at the average market price the wheat farmer realizes a fair profit on his labor and money invested.

Much of the wheat raised in this valley is shipped to the parts of the State where wheat is not grown; some is made into flour for home consumption, while the poorer class is made into a cheap grade of flour, which is sold in China.

The country is well supplied with transportation facilities. Both the Santa Fe and Southern Pacific lines traverse the county, furnishing ready means of outlet both to the markets of the East and San Francisco, and also communicating with the steamship lines which transport the products to foreign markets.

SOIL SURVEY AROUND SANTA ANA, CAL.

By J. GARNETT HOLMES.

INTRODUCTION.

Orange County, though small, is for many reasons one of the richest and most fertile counties in southern California. The county town, Santa Ana, is but an hour's ride by rail from Los Angeles, and all the smaller towns can be reached almost as quickly. Bounded on the southwest by the Pacific Ocean, its ports are in direct communication with all coast-line steamers. Fringed on the north and east by oil-producing foothills, it has within its own borders a cheap and easily transported fuel. Its different agricultural districts produce in abundance the common field crops and semitropical fruits. Its chief agricultural exports are: Of the cereals, wheat, barley, and corn; of the fruits, oranges, lemons, apricots, raisins, grape fruit, and many smaller varieties of semitropical fruits. English walnuts are peculiarly adapted to the climate and form the most important special crop. Celery, onions, and potatoes, which are raised on the lowlands, form an important part of the yearly exportation. Train loads of celery are every winter shipped to the Eastern and Middle States, where it commands the highest market price.

Owing to its latitude and close proximity to the Pacific Ocean, Orange County enjoys a most equable climate and furnishes most favorable agricultural conditions. On account of its healthful climate and nearness to the ocean, the seaports of this county are favored summer resorts. During the winter months it is a favorite resort of the tourist and health seeker from the North and East. Wherever irrigation furnishes a permanent water supply flowers bloom continuously and vegetation of all kinds is most luxuriant.

On account of the diversity and importance of the crops raised and on account of the many different types and phases of soil, this area was selected as a desirable field for the soil-survey work of the Division of Soils. Consequently, early in September, 1900, a party was sent to this region to map the soils and study their physical properties and crop relations. An alkali map, showing the total salt content of the soils, was also made. Copies of these maps, showing the extent and elevation of the various soils and outlining the alkali areas according to intensity, accompany this report.

GEOGRAPHY AND TOPOGRAPHY.

The area surveyed by the Division of Soils includes that portion of the agricultural lands of Orange County found on the Anaheim and Santa Ana sheets of the United States Geological Survey. This amounts to about 300 square miles (192,000 acres). The Pacific Ocean on the south and the foothills on the east and north furnish natural boundaries to the agricultural lands. The 400-foot contour is the limit of cultivable lands. The western boundary is arbitrary, being a line north and south passing through Smeltzer, Westminster, and Buena Park. Santa Ana River enters from the northeast and flowing southwest down across the area to the ocean divides it nearly equally. Except in flood time, all of its waters are diverted for irrigation and this part of its course is merely a bed of sand. But during flood time all of the lower southwestern part of the area, known as the "Las Bolsas Country," is subject to overflow and much damage is done to property and growing crops. One mile north and 1½ miles west of Santa Ana, Santiago Creek joins the Santa Ana, and during flood times its waters greatly augment the overflow below. During very high water a part of the Santa Ana flows down the sandy wash (shown on the map) north of Anaheim, thus making the actual bed of the lower Santa Ana a matter for conjecture.

The topography of this area, without any reference to soils, divides it into two distinct agricultural districts. The 75-foot contour line, running from southeast to northwest across the area, is about the boundary line between these two districts. Very rarely is a fruit tree of any kind or description found below this line. East of the Santa Ana River these lowlands are either sown to alfalfa or the native vegetation is used for pasture. Dairying is the chief industry. West of the Santa Ana, too, there are lands devoted to dairying, but far the greater part of these lowlands are planted to celery and other truck crops. Above the 75-foot contour on each side of the river are found all kinds of semitropical and many tropical fruits and nuts. Although these crops of fruit and nuts may be grown, and in some instances are grown far up on the foothills, it is impracticable in most cases in this area to grow them any higher than the 300-foot contour line on account of the rolling nature of the land and the difficulty of obtaining irrigation water at these levels. The rainfall, occurring as it does in the winter months, affords sufficient moisture for the development of wheat and barley on these uplands. The foothills are of a rounded dome shape.

Lying along the coast east of the low swamp lands of Santa Ana River is an elevation known as the mesa. This rises abruptly, as a bluff, just north of Newport Bay and slopes gently back toward the north. Owing to its peculiar location, it is impossible to obtain water for irrigation, so it too is dry farmed to wheat and barley. To the west of

the swamp lands is a similar area much smaller in extent and only about 50 to 75 feet in elevation. This area is also dry farmed.

GEOLOGY.

The part of Orange County which was mapped is delta plain of very recent origin and the cultivable portion of the surrounding foothills. The entire plain has been reclaimed from the sea by the vast amounts of material brought down by Santa Ana River and Santiago Creek in times of flood and by an elevation of this part of the coast. The remains of a low range of foothills, which at one time must have been submerged some distance out at sea, can be traced along the present coast. That this range is continuous as a sub-formation is proved by the presence of an artesian belt continuing along the landward side of the ridge. At all points immediately on the land side of this low range artesian water is found in abundance at from 90 to 500 feet. Just over the divide, on the ocean side, wells to a depth of more than 1,000 feet have failed to strike artesian water.

Except in flood time, the waters of the Santa Ana sink at the upper margin of the Coastal Plain. It is this water that replenishes the supply of the sand and gravel of the artesian basin. A marked relation is seen in the flow of these wells and the supply from the river. In long seasons of drought, when most of the water is taken out for irrigation above the point of sinking, some of the wells cease to flow and have to be pumped.

The bed of impervious clay, which is from 40 to 80 feet thick and which prevents the escape of the artesian water, must have been deposited in quiet or slowly moving waters. The sand and gravel below the clay contain recent marine fossils, which indicate that the ocean once covered this plain. After the stratum of clay was deposited, there must have been a period of elevation, since now a part of the clay is above sea level. The river continued to bring down a great deal of material in flood times, but when it reached the rising low mud flat, which sloped toward the ocean and was submerged at its lower end, the swiftly moving waters were checked and spread out, depositing their coarser material close to the mouth of the canyon and carrying the finer silt farther down nearer the coast. The low-lying coast range of hills formed a protection against the destructive action of the waves. In this way the delta plain of the Santa Ana was built up.

As might be expected, the building up was much more rapid where the water was first checked, so that near the mouth the land is much higher, with a gradual slope toward the sea. While this plain was being elevated the river flowing out upon it was checked more on the sides, where the water was shallow and where the vegetation grew, than it was in the center, where the water was deep. Hence a greater deposit was made on the sides than in the center of the stream, so that

low banks were built on each side of the swifter moving current, and soon the bed became raised above the surrounding plain. In times of flood, the river broke out, and, in the same way as stated above, it found a new course to the sea, and the process of building up was repeated. Thus, the river has wandered over the delta until it has covered the whole with alternating strips of sand and fine sandy loam, all running in parallel lines southwest toward the ocean. The finer particles of clay were carried to the ocean and deposited years ago. After the lower part of the delta had been built up above sea level, the artesian springs brought about conditions which led to the formation of peat. As these peat beds now exist below the present sea level, conclusive proof is presented that this plain was at one time higher than at present.

This building up by the river of its own bed and banks may now be observed. When the Fifth street bridge west of Santa Ana was built across the Santa Ana River a few years ago the sands were far beneath

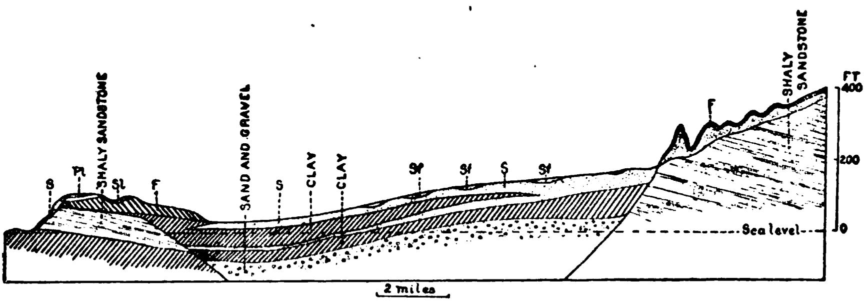


FIG. 42.—Section north and south from foothills to ocean, through Anaheim, Cal.: *S*, Fresno sand; *Sl*, Santiago sandy loam; *Pl*, Placentia sandy loam; *Sf*, Fresno fine sandy loam; *F*, Fullerton sandy adobe.

it; now they come up nearly to the ends of the approaches to the bridge, having been built up 9 feet since the bridge was constructed.

The banks of the river for a half mile or so on each side are covered with willows, which check the water as it tends to spread out and causes it to deposit its sediment. It is only a question of time until the Santa Ana shall again change its course, as even now the bed is in some places higher than the surrounding plains. A section is given in fig. 42 showing the relation of the soils to each other and to the underlying formation.

CLIMATE.

The part of Orange County included in the survey lies on the southern end of the coastal plain upon which Los Angeles is situated. The climate here is the well known, mild, equable climate of southern California. Seldom is it too warm for comfort, and it is never cold enough to injure citrus fruits. Roses, chrysanthemums, geraniums, and many other flowers bloom through the entire winter without any protection. The prevailing winds are from the west and southwest.

Under normal conditions, the most uncomfortable part of the day is in the early morning before the sea breeze sets in; however, when the wind blows all day from the desert, as it sometimes does, it is very warm. These desert winds are locally known as "Santa Ana's."

The following table gives the normal monthly and annual temperatures and monthly and annual precipitations at Los Angeles, Anaheim, Whittier, and Santa Ana; also the normal monthly and annual temperatures of Long Beach. Long Beach, Whittier, and Los Angeles are not in the area mapped, but they are so close that comparisons may be made. As may be seen in the table, the rainfall is in the winter, the summer months having practically none. During the winter much of the weather is cloudy and foggy, although it is not cold enough to make it very uncomfortable.

Monthly and annual normals.

Month.	Temperature.					Precipitation.			
	Anaheim.	Los Angeles.	Santa Ana.	Whittier.	Long Beach.	Anaheim.	Los Angeles.	Santa Ana.	Whittier.
	Deg.	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*In.*	*In.*	*In.*	*In.*
January	54.1	53.0	54.3	56.7	53.6	2.16	2.93	2.31	2.54
February	56.3	55.0	57.2	51.1	54.4	2.38	3.27	2.46	2.13
March	59.1	57.0	59.3	61.1	56.4	2.34	2.98	2.49	2.67
April	62.9	59.0	64.9	65.7	60.4	.72	1.36	.25	.22
May	67.2	63.0	69.4	67.7	63.6	.34	.43	.34	.57
June	69.9	67.0	73.8	73.8	66.4	.06	.10	.00	.00
July	73.0	71.0	76.2	77.8	68.4	T.	.02	.00	.00
August	74.4	69.2	76.5	78.1	70.9	T.	.03	.07	.10
September	71.9	70.0	73.8	75.1	......	.06	.08	.05	.02
October	66.8	64.0	68.0	68.4	64.2	.49	.74	.69	.93
November	60.8	59.0	61.8	63.5	56.6	.80	1.38	.45	.69
December	56.6	55.5	57.2	58.6	58.9	2.46	3.98	2.82	1.78
Annual	64.3	62.1	64.6	66.4	......	12.04	18.20	10.93	11.63

SOILS.

The different soils have approximately the following areas:

Areas of the different soils.

Soil.	Area.	Per cent.	Soil.	Area.	Per cent.
	Acres.			*Acres.*	
Fresno sand	66,380	37.6	Santiago silt loam	14,349	8.1
Fullerton sandy adobe	31,334	17.7	Fresno fine sandy loam	11,552	6.5
Santiago sandy loam	17,100	9.7	Santiago loam	1,830	4.0
Placentia sandy loam	16,857	9.5	Peat	787	.4
San Joaquin black adobe	16,038	9.1			

FRESNO SAND.

Fresno sand, either as soil or subsoil, is spread over more than half of the area mapped and all of the delta of the Santa Ana. Wherever found west of Santa Ana River it is free from gravel and composed of coarse to medium sand. Wherever this sand is underlaid by clay or other heavy subsoil at 20 feet or less it forms an excellent land for fruit or nuts. Along the northern and eastern edges of the artesian belt, where the substratum of clay comes to within from 12 to 20 feet of the surface, is found the ideal soil for English walnuts. This area includes the Anaheim and Santa Ana walnut groves. In the former the sand is found on the surface, while in the latter it is overlaid by 3 or 4 feet of Santiago sandy or silt loam. The soils of the Fullerton walnut groves are to external appearances the same as those of the Anaheim district. The same sandy surface soil is found, but here the subsoil is adobe. The Santa Ana has deposited sand upon the base of the foothills. Since this area is near the mouth of the canyon the deposition has been very rapid and the sand is coarse. Between the Fullerton and Anaheim districts and northeast of Anaheim is a large area, barren except for prickly pear and desert annuals. This is between the lower edge of the adobe subsoil and the upper edge of the first layer of the artesian clay, so there is no heavy subsoil to hold the water. This is clearly indicated in fig. 42. Occasional attempts are made to farm this area of deep sand, but none of the attempts seem to be a financial success.

Other phases of the Fresno sand.—The Fresno sand, which is derived from the Santiago Creek, in many cases contains a high percentage of gravel.

In some cases Fresno sand occurs upon the higher levels. Where this occurs, except along the ocean, it is sand wash from small canyons in the adjacent foothills. The location of these areas can readily be seen by a reference to the soil map. The sand has been pushed out upon the predominating soil, forming a sort of flat sand hill or cone delta. When the small torrents which bring these sands down flow over very precipitous ground, gravel and small bowlders are mixed with the sand.

On the San Joaquin ranch, where the foothills front the ocean, sand is found capping the tops of the highest elevations a mile or more back from the ocean. This is wind-blown, and in most cases is less than 6 feet in thickness. Because of the location these lands are dry farmed to wheat or used as pasture lands, it being impossible to obtain water for irrigation.

The Fresno sand also occurs in the rich, low-lying swampy lands west of the Santa Ana, upon which, when drained, can be grown corn, pumpkins, sorghum, potatoes, and all varieties of truck crops. While it is not considered so good a soil for celery as the Santiago silt loam

or peat of the same area, yet many hundreds of acres of this soil are yearly planted to this crop, which returns a handsome profit. It possesses an advantage over the other celery soils in that celery grown in them must be harvested when it becomes bleached, while in the sand it may be allowed to stand for weeks.

Owing to its open, porous nature and slight capillary power, the sand is usually free from alkali, although between the 50 and 75 foot contour lines small alkaline areas are found.

Mechanical analysis of Fresno sand soil.

No.	Locality.	Description.	Soluble salts.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, .05 to .005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5077	One-half mile N. Anaheim station.	Sand	0.27	1.28	2.93	13.82	11.47	42.48	21.20	4.62	1.92

FRESNO FINE SANDY LOAM.

Only two small areas of this soil are found east of Santa Ana River. The remainder is found west of the Santa Ana, arranged in parallel strips northeast and southwest. In all cases it is underlaid by sand at a depth of 3 feet or less, and is itself only a finer, heavier phase of the sand, having the properties of a sandy loam. It is a better walnut land, and in the swamp area is a better celery soil than the Fresno sand. It is this soil which carries the greater part of the alkali in the alkali belt, and by a comparison of the soil and alkali maps a decided relation between the two is easily seen. Where the alkali is not present in too great quantities, this soil is often sown to alfalfa. On the lower levels no irrigation is necessary, and abundant crops are raised with a minimum of effort. On the lowest levels this soil is interspersed with very thin layers of silt, and sometimes coarser sand, corresponding to the different stages of flood. In some cases thin strata of peat 2 or 3 inches thick are interspersed.

Beginning about 2 miles southwest of Anaheim and running parallel to the other strips of this soil is a hardpan phase of the fine sandy loam. When dry it is very hard and it is almost impossible to plow or work it. On the application of water it softens, but hardens again upon drying. This soil is alkaline, but not enough so to exclude the growth of useful crops. If it were not for the cementing material, which so modifies its mechanical condition that the tender rootlets are unable to penetrate it, this soil could be used for the successful production of crops.

Mechanical analysis of Fresno fine sandy loam soil.

No.	Locality.	Description.	Soluble salts.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5081	One-half mile SW. Anaheim.	Fine sandy loam.	0.34	2.37	Tr.	3.00	3.74	16.46	34.41	35.30	4.57

SANTIAGO SANDY LOAM.

All of this type of soil is found east and south of Santa Ana River. Typically it is underlaid at 3 or 4 feet by sand to a depth of from 12 to 20 feet, when clay is encountered. This soil constitutes the larger part of the orange and walnut districts near Orange and Tustin. Walnut trees thrive upon it much better than oranges, because of their deeper root system; also on account of the altitude, because walnuts for perfect development require the moist fogs to aid in opening their hulls, while fogs are especially injurious to the orange, inasmuch as they give a most favorable condition for the growth of scale. Truck crops, peanuts, and all the smaller varieties of fruits do exceptionally well upon this soil. It is kept in good mechanical condition with very little effort, and there is an abundance of irrigation water for such crops. Like the sandy soil of this region, it is found occupying some of the higher elevations. In such cases it usually has for a subsoil the sandy adobe. These upland areas are dry farmed to wheat and barley, and the broken nature of the country will never admit of irrigation.

Mechanical analysis of Santiago sandy loam soil.

No.	Locality.	Description.	Soluble salts.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5079	Three-fourths mile NE. Santa Ana.	Sandy loam.......	0.20	2.79	1.75	4.84	5.30	25.94	26.93	26.72	6.64

SANTIAGO SILT LOAM.

The greater portion of this soil is also east of Santa Ana River, though there are small areas on the western side. The largest area

is that which includes the city of Santa Ana. Like the Santiago sandy loam, it is typically underlaid by sand, but south of Santa Ana, where it grades into the San Joaquin black adobe, it has an adobe subsoil. When low lying, this soil is alkaline; such areas are planted to alfalfa rather than to fruit, which would be injured. It yields three or four cuttings per year without irrigation. That part, however, which is situated above the bottom lands is planted to much the same varieties of trees and shrubs as the Santiago sandy loam. Just south of McPherson a gravelly phase of the silt loam covers quite a large area. This gravelly phase is now planted to oranges, grapes, and smaller fruits, although before the grape disease killed the vines of southern California this soil was noted as exceptionally good for the production of raisin grapes. The pebbles range in size from coarse sand to bowlders as large as a man's head. The larger ones are removed from the field; the smaller ones do not seem to interfere with cultivation.

The silt loam west of Santa Ana River, with the exception of the one area in the most southerly part, which is very alkaline, is farmed to celery. This loam is in most cases only about 2 feet thick, is underlaid by sand and is considered the best land for celery. When next to the peat land, it shows the influence of standing water, and is rather heavier than that east of Santa Ana River. With the exception of the large swampy area on the extreme south, almost every acre of Santiago silt loam west of the Santa Ana is now farmed to celery. The swamp areas were originally covered with a dense growth of willows, nettles, and tules, so that it required a great deal of labor to prepare them for cultivation, but now they amply repay the owners for all the time and money expended in reclaiming them.

Mechanical analysis of Santiago silt loam soil.

No.	Locality.	Description.	Soluble salts.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5083	1 mile NE. Santa Ana.	Santiago silt loam.	0.26	3.65	Tr.	3.78	1.83	13.53	23.75	43.68	9.56

SANTIAGO LOAM.

Santiago loam is a true loam. The largest area is found about a mile and a half north of Orange, while another area includes the little town of El Modena. There are only about 3 square miles all told of this soil. It is characteristically barren, or nearly so. In no case was a

first-class crop found growing upon it. It is underlaid by sand and gravel at a depth of from 3 to 6 feet. From the surface down it gradually becomes a heavier loam until a depth of about 3 feet is reached; then the lower sands begin to have effect, giving rise to a sandy loam. Native vegetation is sparse, and when wheat and barley have been sown only an indifferent crop is grown. The surface of the area north of Orange is comparatively level, except for a few small "arroyas," while at El Modena it is rough and broken, containing some gravel, which is not the smooth, rounded gravel found in the adobe and silt loam, but is sharp and angular. No cause can be assigned for the barrenness of this soil.

Mechanical analyses of Santiago loam.

No.	Locality.	Description.	Soluble salts.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5086	1¼ miles N. Orange.	Loam, 0 to 12 inches.	0.14	3.04	Tr.	2.55	1.61	8.88	24.75	43.07	15.91
5087	.....do............	Subsoil...........	.33	3.54	Tr.	2.67	.85	6.39	23.52	41.60	20.89

SAN JOAQUIN BLACK ADOBE.

This soil has the largest area of any soil east of the Santa Ana. It lies principally east and south of Santa Ana. Almost all the low-lying part of the San Joaquin ranch south of Tustin to the Laguna road is of this soil, which is the heaviest type of the Santiago soils. It extends from less than 25 feet above sea level to the 400-foot contour line. In the higher levels it is planted to fruit trees of various kinds and varieties. It is not so good a soil for trees as the lighter soils, since the roots find difficulty in penetrating it. When dry it breaks up into little cubes, forming a sort of mulch on the surface, and as the dry season advances this mulch gets thicker, giving rise to the peculiar phenomenon known as "dry bog." Great care must be exercised in plowing or the soil will be puddled and become absolutely impervious to water. For dry farming it is usually plowed dry and, to avoid puddling, the wheat is sown after the rain. In the orchards it requires constant watching after irrigation to determine the proper time to cultivate in order to keep it from baking.

Some of these upland black-adobe soils have gravel mixed with them in much the same proportion as the gravelly phases of the sandy and silt loams. This gravelly phase of the black adobe is better for fruit trees than the typical adobe, since the gravel somewhat relieves its sticky, compact nature and makes it more easily penetrated by the

roots. The low-lying areas of this soil are very heavy and sticky and usually carry alkali. These lands when alkaline are used for pasture only. The native vegetation is salt grass, pickle weeds, and other saline plants. Where this soil is less than 20 feet above sea level the ground water comes within less than 6 feet of the surface, and thus keeps the ground moist the year round. Some areas that were originally under water and have been recently drained are free from alkali. These areas are planted to corn and other shallow-rooted crops, and give an excellent yield.

Mechanical analyses of San Joaquin black adobe.

No.	Locality.	Description.	Soluble salts.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5092	¼ mile E. 4¼ miles S. Santa Ana station.	Black adobe	3.29	10.60	1.86	4.28	2.86	4.44	8.49	41.34	23.25
5093	do	Subsoil	......	3.67	2.52	1.52	.74	1.94	6.30	55.84	26.98

FULLERTON SANDY ADOBE.

Usually this soil is known as the "foothill soil." It comprises the covering for all of the foothills surrounding the Santa Ana Valley. The largest area mapped is found in the rolling country north of Fullerton. Unlike the black adobe, this soil contains quite a high percentage of sand, as the analyses show. When dry it cracks open and breaks up into cubes, giving rise to a condition similar to that found in the black adobe, but not so marked. Because of its elevation and the usual rolling nature of the surface this soil is only dry farmed. In no case is any considerable area irrigated. All of the foothills that are not too steep for cultivation are sown to wheat and barley. This foothill soil is the greatest grain producer of southern California. Owing to its peculiar method of breaking up when dry, it is at each succeeding rainy season in an excellent condition for receiving moisture, with which it parts very slowly, hence furnishing a storage for the dry months. It is underlaid at a depth of from 3 to 6 feet by sand, gravel, or shaly sandstone, but with the present methods of farming the subsoil has little influence upon the crops cultivated. As the Fullerton sandy adobe soil packs hard and does not become dusty so soon as the other soils of this region, it is much used as a covering for the roads where they are formed of a lighter soil. Roads thus made and sprinkled are, except in rainy weather, as firm and compact as the pike roads of the East. Where streams cut gullies and small canyons

through this soil the sides stand up perpendicularly, showing seams and cracks the entire thickness of the soil.

Mechanical analysis of Fullerton sandy abode.

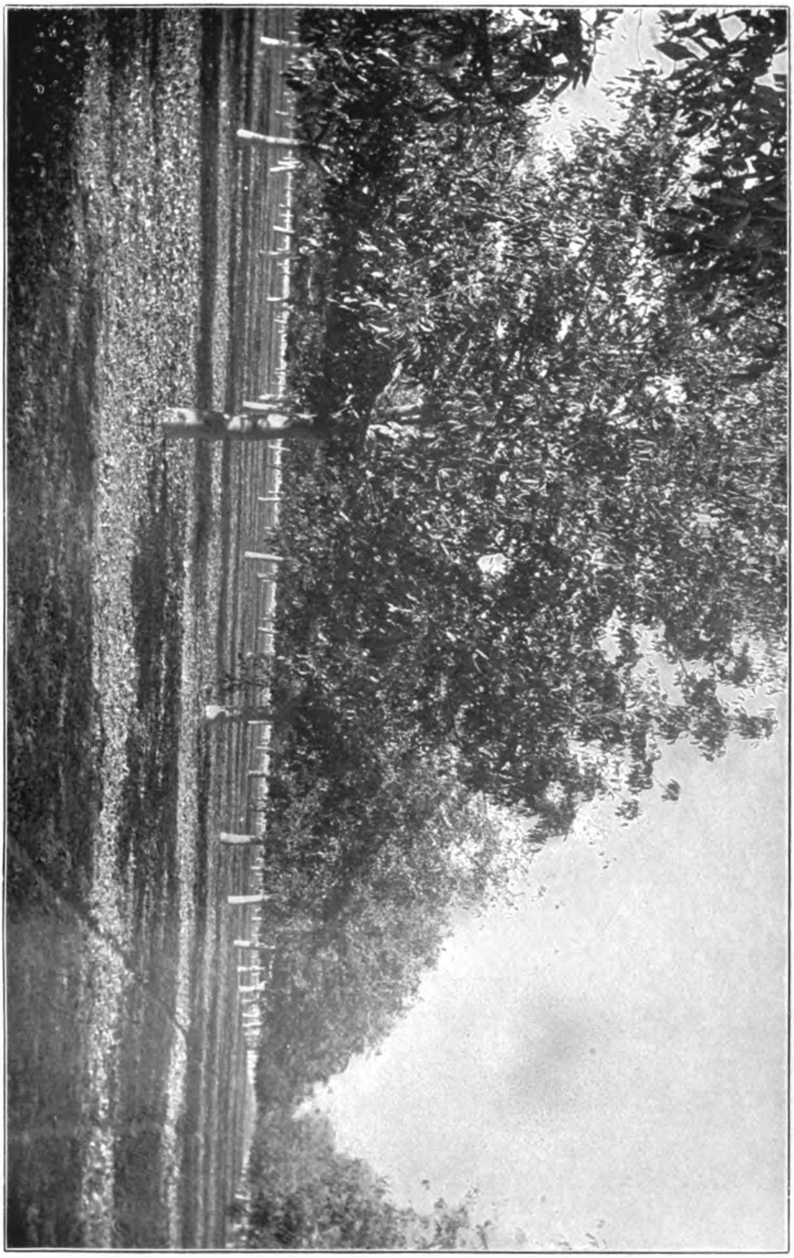
No.	Locality.	Description.	Soluble salts.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5094	2 miles S. Smeltzer Station.	Sandy adobe....	0.38	29.4	1.54	3.49	3.90	11.82	32.18	32.04	12.10

PLACENTIA SANDY LOAM.

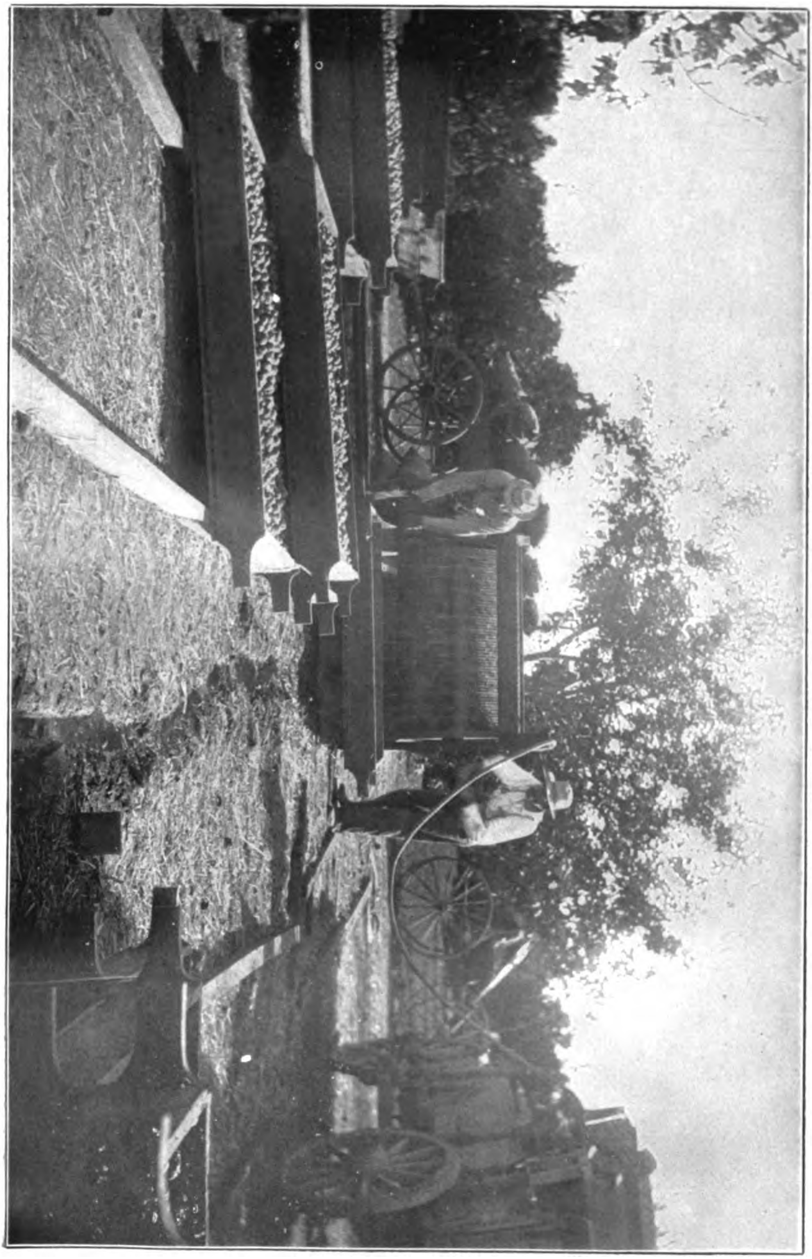
The largest area of this soil covers what is called The Placentia Country. It differs from the Santiago sandy loam in that it is partly windblown soil and has a heavy subsoil. The Placentia Country, lying northeast of Fullerton, is the only area of any considerable size that is level enough for irrigation. The rest is like the sandy adobe, rolling and broken, and is dry-farmed to wheat. This level Placentia tract is considered the best soil for oranges in Orange County. The soil is from 2 to 3 feet in thickness, of a light loamy texture, and is composed principally of very fine sand and silt. Underlying this is the sandy adobe. Where not of so compact a nature as to be impervious to water this subsoil acts as a storage and preserves moisture which may be used in seasons of drought. The roots of the orange penetrate this subsoil and use this store of moisture. To some plants it is quite impervious. English walnuts, for instance, when planted upon this soil soon die, because the taproot is unable to penetrate the subsoil. Practically all the first-class oranges shipped from Orange County come from this area.

In small areas this soil is found with a subsoil of sand underlaid by adobe, forming a loose soil and subsoil from 12 to 15 feet thick. On these areas English walnuts thrive especially well, the heavy adobe keeping the water from seeping away below and the loamy soil on the surface being easily tilled, while the sand is readily penetrated by the spreading roots.

The mesa land, which rises as a bluff along the coast south of Santa Ana, is of this same kind of soil. There is no irrigation, it being impossible to obtain water in any other way than by pumping.



English Walnut Grove near Fullerton on Placentia Sandy Loam, underlaid by Fresno Sand Subsoil.



WASHING AND DRYING ENGLISH WALNUTS.

Mechanical analyses of Placentia sandy loam.

No.	Locality.	Description.	Soluble salts.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
5096	4 miles E. three-fourths mile N. Fullerton.	Sandy loam, 0 to 30 inches.	0.09	1.75	1.65	5.83	8.04	22.53	34.40	17.38	8.15
5097	.....do............	Subsoil sandy loam, 30 to 72 inches.	0.19	2.73	1.65	4.00	5.00	20.22	23.98	24.84	17.64

PEAT.

Perhaps the most interesting soil of the Orange County region is this peat land. It varies in depth from a few inches to 30 feet, and is found along the low-lying artesian belt. The district mapped does not include all of the peat lands of Orange County, but typical areas were encountered which gave a working knowledge of the whole. Most of this soil lies west of Santa Ana River, though two small areas were found on the eastern side. One of these, on the San Joaquin ranch, is very deep, 10 to 30 feet. The other, which is found south of Santa Ana on the ranch of Mr. William McFadden, is not so deep, being at its deepest part only 23 feet. Both of these areas are much deeper than the average, and, when properly "subdued," will be valuable tracts. They have been drained and cultivated for two years only, so as yet do not yield full crops. The tracts west of the Santa Ana have nearly all been cultivated for several years and are now yielding full crops. Wherever the peat is continuous for a foot or more, peat springs are found and the overflow waters of the rivers have deposited their sediment before reaching this district. The whole county, being of a low swampy nature subject to periodic overflow, is continuously wet a few inches below the surface. Where springs occur an actual swamp is found the year round. Here the tules, nettles, hummock grass, wild celery, and other swamp plants have grown up, made their yearly deposit of vegetable matter, the roots always keeping near the surface and the old roots dying below, until there is a mass of decayed vegetable matter which is known as peat. In these patches of peat, if small, there is usually but one spring, and this spring is found in the center. As it comes up from below it brings silt and fine sand, which it deposits at the surface. Fig. 43 gives an idea of the formation of these peat lands.

From their peculiar method of formation these peat lands are higher than the immediate surrounding country. After they are thus built up for a time the spring seeks another outlet, breaks through the peat at some point lower than the central cone and here deposits its silt, so that in all areas of peat these patches of silt and fine sand are found. The larger areas are formed by several springs operating

near enough together to flood the entire area. Some of these springs are situated in the line of waters heavily charged with sediment. Here are found layers of peat alternating with layers of silt and fine sand. A period comes when no great floods occur and the peat is deposited, then comes the flood and deposits its layer of sediment. This process has been going on for a great number of years. In some places these thin layers of peat are found 30 feet below sea level.

A few years ago the entire country known as the "Bolsa Country" was a swamp, and considered of no practical value. Willows, tules, nettles, and other swamp growths were the only vegetation. A few enterprising farmers organized what is known as the Bolsa Drainage Ditch Company, and put in a small ditch, which drained a limited area near where Smeltzer is now situated. In a short time it was demonstrated that it would pay to drain and farm this land, so this ditch system was enlarged and extended until it now has three branches, known as the Bolsa, Blue Channel, and South Branch. They have an aggregate of 13 miles of main ditch, with a common outlet to the ocean. Narrow trenches, emptying into these main

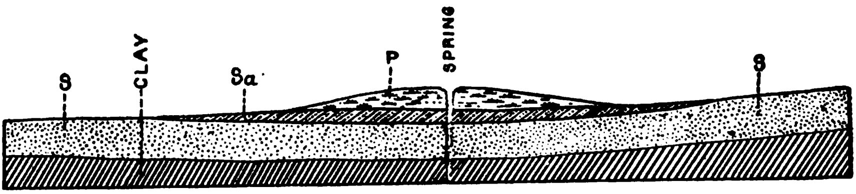
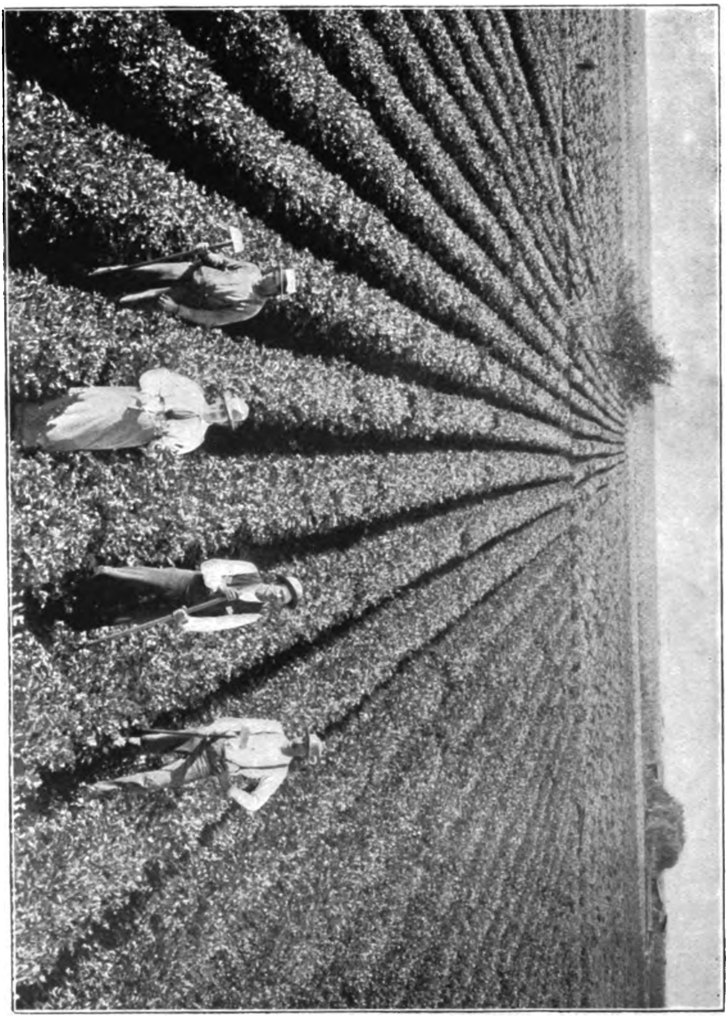


FIG. 43.—Section through peat land, showing artesian spring and cause of the accumulation of peat: *S*, Fresno sand; *Sa*, Santiago silt loam; *P*, peat. These peat lands owe their origin to springs of artesian source, which give rise to swamps, in which vegetable matter has accumulated, so that these peat lands are higher than the surrounding areas. They are found only in low places which are not subject to overflow from the rivers.

ditches, are cut through the peat with hay knives or peat spades, which with the exception of the trenches carrying off the waters of the springs, are filled so soon as the surplus water is drawn off. Great difficulty is experienced in plowing the first time. The lands are boggy and are filled with the roots and stumps of plants and willows. The stumps have to be first grubbed, and the peat tussocks, great bunches of grass roots, have to be cut off. Peat shoes are then placed upon the horses and the difficulty really begins. Peat shoes are usually made of the two ends of a tobacco box securely nailed together, the corners rounded, and clamped to the hoofs of the horses. Horses soon learn the value of these shoes and venture fearlessly upon the boggy land. Without them they would immediately be submerged. Occasionally a horse that does not understand the use of these shoes will get "bogged." No attempt is made at subsequent cultivation the first year. Usually corn is dropped in one furrow and potatoes in the next, thus alternating until the whole field is planted. In this way, and with no further cultivation, often 100 bushels of corn and 300 bushels of potatoes are raised on the same acre of ground at the same time. So soon as the surface covering has become suffi-



CELERY FIELD NEAR SWELTZER STATION.

ciently rotted to admit of cultivation the land is planted to celery, the staple crop of the peat lands.

The Bolsa Drainage Ditch Company is a cooperative corporation owned by the farmers benefited by it. The cost for the next ten years has been estimated by the board of directors at $15,000 for the draining of 5,000 acres. A part of this sum was immediately assessed the owners benefited by the ditch, the assessment being according to the value of their land and the degree of benefit derived from its drainage. This amount is decided by the board of directors, and is to be used in immediate improvement of the system. The remainder, included in the general assessments, is paid when the farmer pays his yearly taxes. This method occasions some discontent, as it is impossible to estimate just how much each is benefited, but on the whole it is perhaps the best known method of administrating such cooperative companies.

In 1898 a few enterprising men, encouraged by the success of the Bolsa drainage system, organized what is known as the Willows Drainage Ditch Company. This company was to drain that portion of the delta of the Santa Ana situated between the two bluffs near its mouth and back about 6 miles from the ocean. The original cost was to be $1 per acre for all lands benefited by the ditch, and subsequently a small tax was to pay the expenses of maintaining the ditch. Enough money was raised to put in the ditch, but this indiscriminate tax worked a hardship upon some who were not so greatly benefited as were their neighbors, so they refused to pay as much tax as their neighbors paid. Then all refused to pay tax, and the result is that after a period of three years' drought the ditch is now barely capable of carrying off the surplus water. What the condition will be if a flood shall occur is a matter for speculation. Many of the lowest farms, at least, will be submerged, the crops ruined, and the families compelled to seek higher ground until the waters subside. It is hoped that the matter will be so adjusted that an adequate permanent system will be inaugurated. The land is valuable enough to support an extensive system. From a tule swamp, practically valueless, it has been advanced to land now worth from $100 to $250 per acre, and when a reliable system of drainage is permanently instituted the land will be worth even more.

Under this drainage ditch there is no very deep peat. It is here that the layers of peat alternate with those of sand and silt, making soils fully as valuable as the peat lands, since they are much more easily cultivated and grow practically the same crops. Their greatest disadvantage is their location in the flood path, but this will be partly overcome by a first-class system of drainage.

Peat when cut in chunks and dried makes a good fuel. The tussocks and the poorly-rotted peat from the ditches are often burned as fuel. The well-rotted peat is much desired by florists and greenhouse men, who use it to mix with heavier soil for potted plants. For this purpose considerable is barreled and shipped away, bringing about $1 per barrel.

After being farmed for a number of years, peat lands pack down and become noticeably lower in elevation than before. They also get

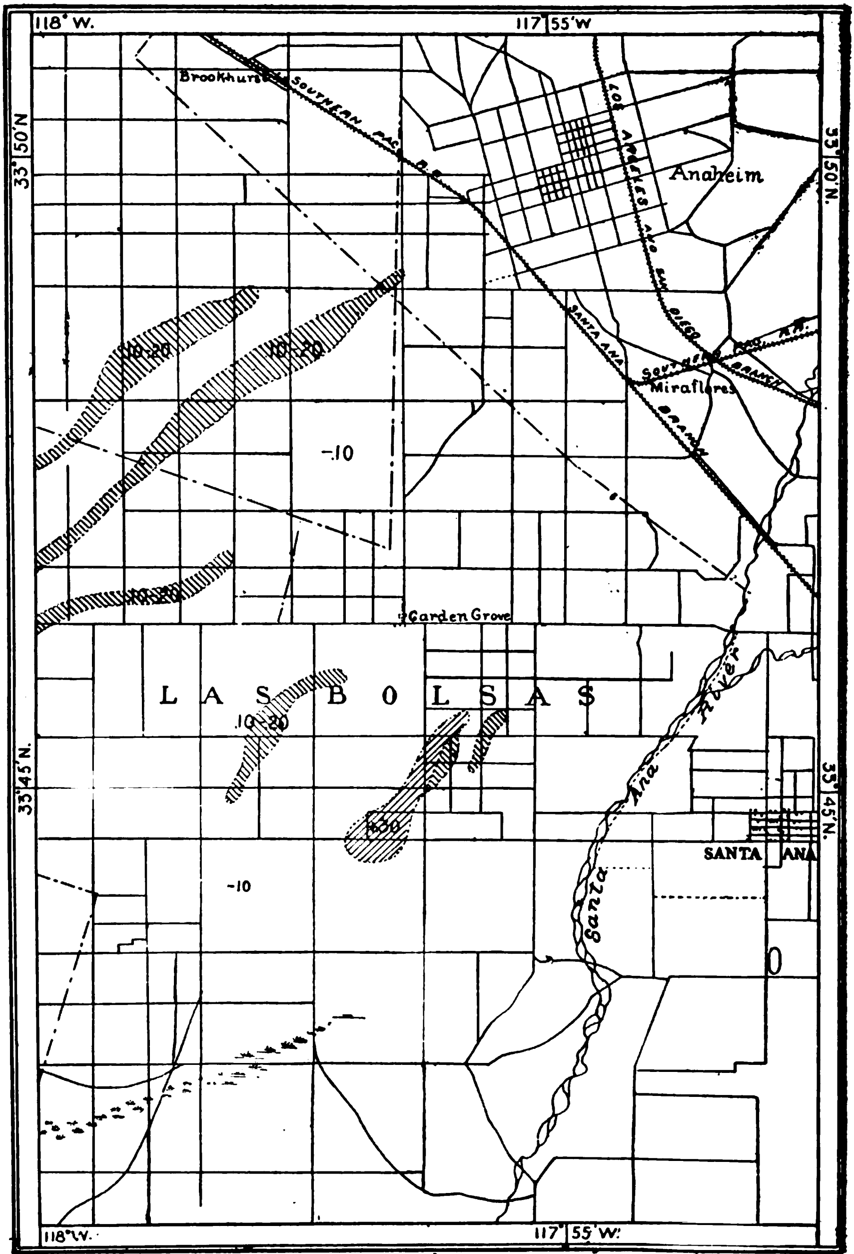


FIG. 44.—Black alkali lands of Santa Ana sheet, showing lands containing less than 0.10 per cent, from 0.1 to 0.2 per cent, and more than 0.3 per cent of sodium carbonate.

correspondingly heavier until, in some cases of lands that have been farmed for a number of years, the aid of a microscope is required to

detect their origin in the small amount of fibrous matter remaining. Some of the deepest peat, and therefore that which will settle the most, is only a little above tide water. It is a question whether this land will not some day be lower than the level of high tide.

First-class peat land, thoroughly "subdued" and situated above flood line, is now worth $500 per acre, and will pay interest on even a larger investment.

ALKALI.

A reference to the alkali map will show that the alkali east of the Santa Ana, of this region, occurs as a large and continuous area of varying intensity, in all 13,150 acres. On the western side it is in narrow strips. There is about 9,600 acres in these small areas. In only a few places do any of these strips or areas extend above the 100-foot contour line, the lands above this line being practically free from alkali.

These alkali lands have never been irrigated, but are always moist through subirrigation. The alkali is all found accumulated in the first two or three feet of the soil, with the greater part as a crust on the surface. A number of chemical analyses of these crusts, made in the Division of Soils, show the salts to be principally white alkali, in this case the sulphates with the chlorides—common salt and magnesium chloride. But a few isolated spots of black alkali (sodium carbonate) occur, which are shown on the sketch map, fig. 44.

Chemical analyses of alkali crusts of Orange County.

Constituent.	5102. One-half mile E., 1 mile S. Smeltzer.	5103. 6 miles S. Santa Ana.	5104. San Joaquin Ranch.	5105. 2¼ miles SW. Tustin.	5106. 1¼ miles SW. Red Hill.	5107. 2 miles NW. Santa Ana.	5108. 2 miles S., one-half mile W. Santa Ana.	5109. 2¼ miles SW. Tustin.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ca	0.49	....	1.80	1.46	3.02	2.80	1.79	1.32
Mg	.70	....	2.71	7.71	2.21	3.11	4.65	7.94
Na	34.93	25.73	32.21	19.46	26.28	25.04	22.93	18.09
K	.18	.22	.44	.54	1.40	.78	1.35	.29
NO_3	....	....	....	....	10.93	18.14	....	....
SO_4	25.52	27.76	6.27	50.74	27.93	24.74	59.84	70.48
Cl	37.85	10.39	56.14	18.46	24.96	23.57	7.73	1.22
CO_3	....	15.36	....	....	....	....	....	....
HCO_3	.33	10.54	.43	1.63	3.27	1.82	1.71	.66
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
$CaSO_4$	1.67	....	6.13	4.93	10.25	9.53	5.61	4.49
$MgSO_4$	3.49	....	2.45	38.18	10.96	15.39	23.06	39.37
$MgCl_2$	....	....	8.68	....	....	....	....	....
KCl	.34	.41	.84	1.03	2.66	1.49	2.58	.55
Na_2SO_4	31.94	41.11	....	24.00	17.71	8.46	55.69	53.11
NaCl	62.10	16.81	81.31	29.61	39.03	37.68	10.73	1.57
$NaNO_3$	....	....	....	....	14.99	24.95	....	....
Na_2CO_3	....	27.16	....	....	....	....	....	....
$NaHCO_3$	.46	14.51	.59	2.25	4.40	2.50	2.36	. 1
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Per cent soluble	50.56	33.34	27.92	19.22	10.59	13.27	12.73	54.92

Sample No. 5104 was collected on the San Joaquin ranch, about a mile back from the head of San Joaquin Bay, but on land that is only a few feet in elevation above tide, and which evidently has been affected at some recent time by tide water. Chemical analyses of the salts of the sea water and of this sample of alkali crust follow. The composition of the salts of the sea, as determined by Regnault, is the mean result of over twenty analyses.

Composition of salts of the sea and of crust 5104.

Salts.	Ocean salts.	Crust 5104.	Salts.	Ocean salts.	Crust 5104.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Sodium chloride	77.04	81.31	Magnesium bromide	0.06	
Potassium chloride	1.99	.84	Calcium carbonate	.08	
Calcium sulphate	3.99	6.13	Sodium bicarbonate		0.59
Magnesium sulphate	6.56	2.45	Total	100.00	100.00
Magnesium chloride	10.28	8.68			

The striking similarity of the composition of sea water and of the alkali of this crust leads to the belief that at least a part of the alkali here owes its origin to the evaporation of ocean water.

Taking the other extreme of the alkali lands, that is, the crusts from near the highest elevation (No. 5108), its composition is—

	Per cent.
Sodium chloride	10.73
Potassium chloride	2.58
Calcium sulphate	5.61
Magnesium sulphate	23.03
Potassium bicarbonate	2.36
Sodium sulphate	55.69
Total	100.00

This crust was collected from the San Joaquin black adobe land 2 miles south of Santa Ana Station and a half mile west. A comparison of this sample with the one from near tide water (No. 5104) shows a difference in the composition of the alkali; here it is mainly the sulphates. Thus, the alkali varies from a predominance of the sulphates on the higher parts of the alkali lands to a greater percentage of the chlorides on the lowest. Between these two extremes varying proportions of the two are found.

The large area of alkali south and southeast of Santa Ana occurs mainly in the San Joaquin black adobe soil, being the largest continuous area of alkali in this region. All the land which carries more than 0.60 percentage of alkali is used for pasture land, no attempt being made to grow crops other than the native saline vegetation. But where a less percentage of the alkali is present alfalfa forms a very productive and remunerative crop.

In no place is there any irrigation upon this alkali land, except in

very small plots, where the water from artesian wells is utilized. The irrigation company does not include this land in its district.

West of the Santa Ana the alkali occurs in strips. In most cases it is the Fresno fine sandy loam that carries the alkali, as will be seen by a comparison of the alkali and soil maps. Here, too, all of the alkali lands are used for pasture. The country is divided into farms of from 40 to 100 acres, and on almost every farm there is some land that will produce alfalfa. This, with the native vegetation, furnishes sufficient feed to maintain the dairying industries to which these farms are devoted. Very few attempts are made to raise anything but alfalfa, which once seeded grows luxuriantly without irrigation.

It was found to be extremely difficult to establish the amount of alkali that the different fruit trees could withstand, for in most cases no attempts are made to grow trees upon the alkali soils. Then, too, the nearness of the water table to the surface in these low lands makes it impossible to distinguish between the effects of alkali and of standing water. Enough was learned to know that English walnut trees are always excluded by more than 0.15 per cent of alkali. This amount does not appreciably affect pear trees or apple trees, as they will grow in soil that has as much as 0.50 per cent, but are measurably affected by it, and as this amount increases they rapidly die. Asparagus, alfalfa, onions, corn, and celery are able to withstand varying amounts from 0.20 to 0.60, in the order in which they are named, asparagus being the most resistant and celery the least. Nothing but saline vegetation grows upon a soil having more than 0.60 per cent, although much of this vegetation is good pasture for stock.

Knowing the kind and amount of the alkali, the nature of the soil and subsoil, and the kind of crops best adapted to such alkali soils, the landowner can proceed intelligently in the treatment of such soils, having in view their ultimate reclamation. For the alkali soils west of Santa Ana River this reclamation is practicable and should be accomplished at slight cost. If the surplus of ground water can be carried off in drains and not allowed to evaporate from the surface, no more alkali will be accumulated. Since the whole country has an open, porous, sand subsoil, and much of the surface soil itself is sand, a few irrigations with proper drainage would suffice to entirely reclaim that which now has only a small amount and to relieve even the worst spots so that the alkali-resisting plants may be grown upon them. The Willows and Bolsa drainage ditches even now drain much of this country, and if they were enlarged and extended so as to take in all of the country affected by alkali the expense to the present owners of the ditches would be much less, because of the division of expenses, while it would be cheaper for the owners of the alkali lands to thus make use of these outlets than it would be to dig ditches to the sea.

Mr. Frank Hazard, near Westminster, has demonstrated that tile drainage when practiced on isolated spots is very beneficial. On

spots where a few years ago nothing of value would grow he now has a good stand of alfalfa, the change being brought about by the use of tile drains, with the Bolsa drainage ditch as an outlet.

The alkali east of Santa Ana River occurs in a heavy soil, mainly the black adobe, so its reclamation will be more difficult than that of sandier soils, because the alkali is not so easily washed out, as water travels slowly through a heavy soil. With plenty of irrigation water and with proper tile drainage this soil might in time be made valuable for alfalfa and other alkali-resisting plants.

HISTORY AND PRESENT SYSTEMS OF IRRIGATION.[1]

The earliest canal in this section of which there is any authentic record is the Yorba ditch, which was built by Bernardo Yorba in 1835, Mr. Yorba being at that time sole owner of the rancho Cañon de Santa Ana. Two other ditches were also constructed by him about this time, but in a flood of 1862 all three of these ditches were destroyed. After this destruction the present Yorba ditch, based upon the rights of the old ones, was constructed. This ditch has the oldest water rights on the river, and such rights are respected by the owners of the other ditches. It irrigates only about 600 acres of land and carries on an average 450 inches of water.

A few years after the Yorba was built the Kramer ditch was constructed, its purpose being to irrigate that part of the rancho San Juan y Cajon de Santa Ana, known as the Kramer tract. After the construction of the Anaheim ditch the Kramer received its water through the head works of this canal. When the western companies were finally consolidated into the Anaheim Union Water Company, this ditch received 20 shares of nonassessable stock as a recognition of its prior rights.

In 1856 the organization generally known as the Anaheim Colony was formed in San Francisco, under the name of the Los Angeles Vineyard Association. The association secured 1,165 acres of land from the rancho San Juan y Cajon de Santa Ana, with water rights based on the riparian rights of this ranch, and with additional water rights purchased from the owners of the rancho Cañon de Santa Ana, which was also riparian to the river.

In 1857 the first ditch of this company was dug and enough water diverted to irrigate the 1,165-acre tract. At first there was no separate incorporated water company, but in 1859 the Anaheim Water Company was incorporated. The stock was divided into 50 shares, and was appurtenant to the 50 lots of the Los Angeles Vineyard Association. In 1878 the Anaheim Water Company purchased a half interest in the Cajon Irrigation Company's ditch, which was then in process

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[1] The information in this chapter was obtained from officials of the Santa Ana Irrigation Company, the Anaheim Union Water Company, and "Irrigation in Southern California," by William H. Hall.

of construction. A flume about 7,000 feet long was constructed the following year, connecting the Anaheim with the Cajon Canal. For several years the Anaheim received all its water in dry seasons from the Cajon, but this joint use of the same canal led to friction. In 1882, pending the decision of the courts, the Anaheim constructed what was known as the Anaheim New Canal, tapping the river at a point almost opposite the Santa Ana Canal of the south side, and thus getting a permanent supply from the river itself. The Cajon Canal was begun in 1875 by the commissioners of a local district, formed under irrigation district laws, and was to irrigate the country now known as The Placentia Country, and that north of the old sand wash between Anaheim and Fullerton. The tax, however, was too great and many of the landowners refused to pay it, so great difficulty was experienced in getting funds, as well as in the litigation which was started. This led to general dissatisfaction, and in 1884 the Anaheim Union Water Company was formed. To this company was conveyed the interests of all the canals on the north side, except the Yorba.

This Anaheim Union is the company that now supplies the Anaheim, Fullerton, and Placentia districts with water. Since this union was effected great improvement has taken place in the service of the company. The main ditch, where it flows over the sandiest portion of its course, has been cemented for 2 miles at a cost of $4 per linear foot. This greatly augments the amount of water that formerly reached the district. The company also has 33 miles of cement laterals and distribution ditches, which cost from 25 cents to $1.50 per linear foot. The rates charged for water are decided upon from month to month by the board of directors, being more when the water is scarce than when the supply more than meets the demand. For the year 1899 the rates were, for 100 inches one hour, during January, February, November, and December, 30 cents; for March, 40 cents; for April and October, 50 cents; for June, July, and August, 80 cents; for September, 60 cents. At this rate it costs about $4 per year per acre to irrigate walnut orchards and $6 per acre for irrigating orange trees and alfalfa. A list of prices is prepared for the filling of cisterns, watering of stock, sprinkling of lawns, etc.

Except for the small amount diverted by the Yorba Canal the Anaheim Union now has one-half of the water of the lower Santa Ana River. Its main head gate and that of the Santa Ana Valley Irrigation Company are situated on opposite sides of the river, so that one dam is all that is necessary for the two. No permanent dam has been put in, only a brush dam, which is washed out in time of flood and again replaced when the water subsides.

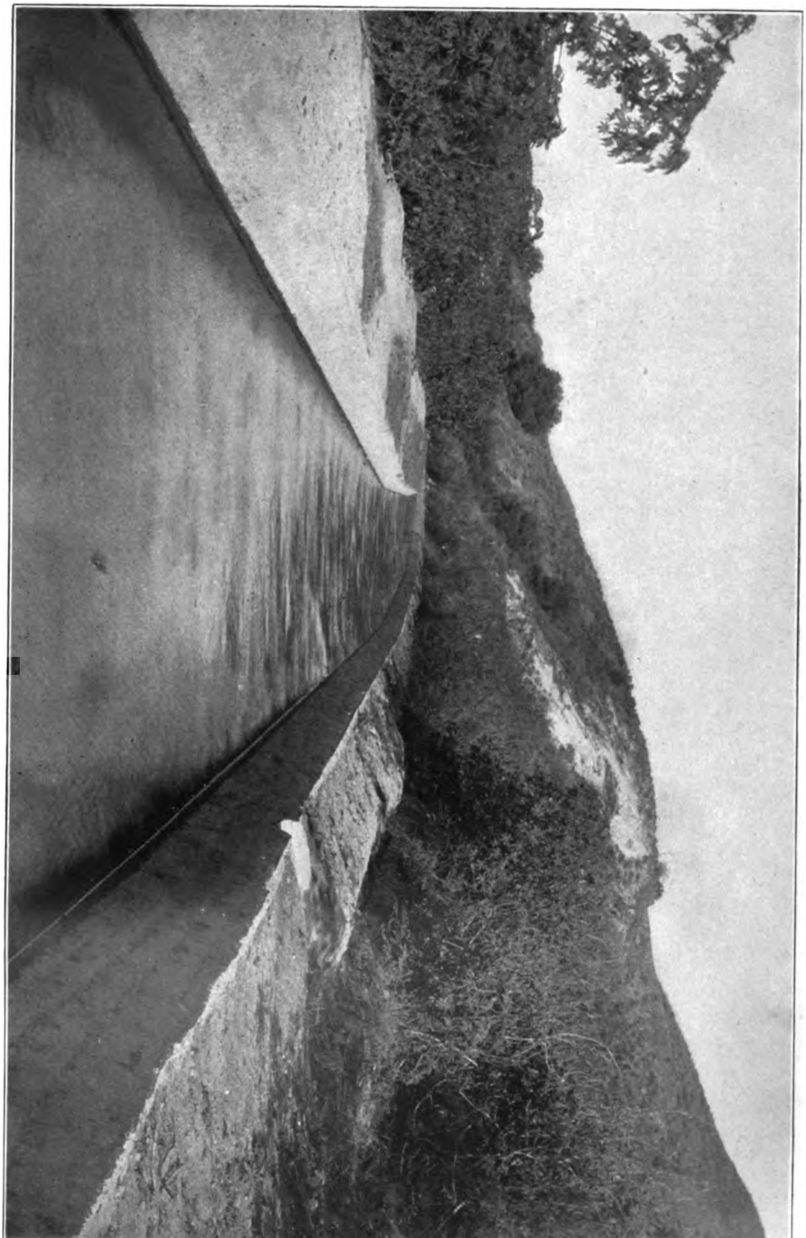
Irrigation on the south side of the Santa Ana begun with the Semi-Tropical Water Company, formed in 1873. This was solely a water-supplying company, owning no land, but simply selling water for irrigation purposes. This company diverted water with the consent of

the owners of the rancho Santiago de Santa Ana, who claimed that by their original grant and riparian rights they were entitled to half of the water of the Santa Ana. In 1877 a suit occurred between the Semi-Tropical and Anaheim Union companies that was carried to the United States Supreme Court, where the decision of the lower court, which had decided in favor of the Anaheim Union, was reversed, and an equal division of the water advised. This advice was followed, and since that time, 1883, no friction has occurred. In 1877 the present corporation was formed—the Santa Ana Valley Irrigation Company. It immediately acquired all of the interests of the Semi-Tropical Company, and it is the irrigation company which provides all the water east and south of the Santa Ana River. While nearly all southern California has been suffering for water during the last two or three years, this company has had sufficient. Instead of the price of water advancing, as it has in nearly every other section, it has been diminished. Before the dry season the ditch had to be kept up and employees' salaries paid, and all the water was not sold; but now all the water available is sold, and the consequence is that it costs less to irrigate than it did in seasons of greater rainfall. During the past year, under the Santa Ana Irrigation Company's works, it cost but $1 per year to irrigate walnut orchards and $1.75 for orange trees and alfalfa. This is somewhat less than the cost of irrigating similar lands on the other side of the river, which is partly due to the more open, porous nature of the soil on the north side. This company has about 100 miles of ditch, including laterals and distributing ditches, and 26 miles of this is cemented, at a cost of from 25 cents to $1.50 per foot. The policy of the company is to have eventually its entire system of ditches cemented, so that there will be a minimum loss in transmission.

Neither the Santa Ana Valley nor the Anaheim Union districts extends into the low-lying land. All the irrigation water used on these lowlands comes from artesian wells. Of these wells, there are a great number of different sizes and capacities.

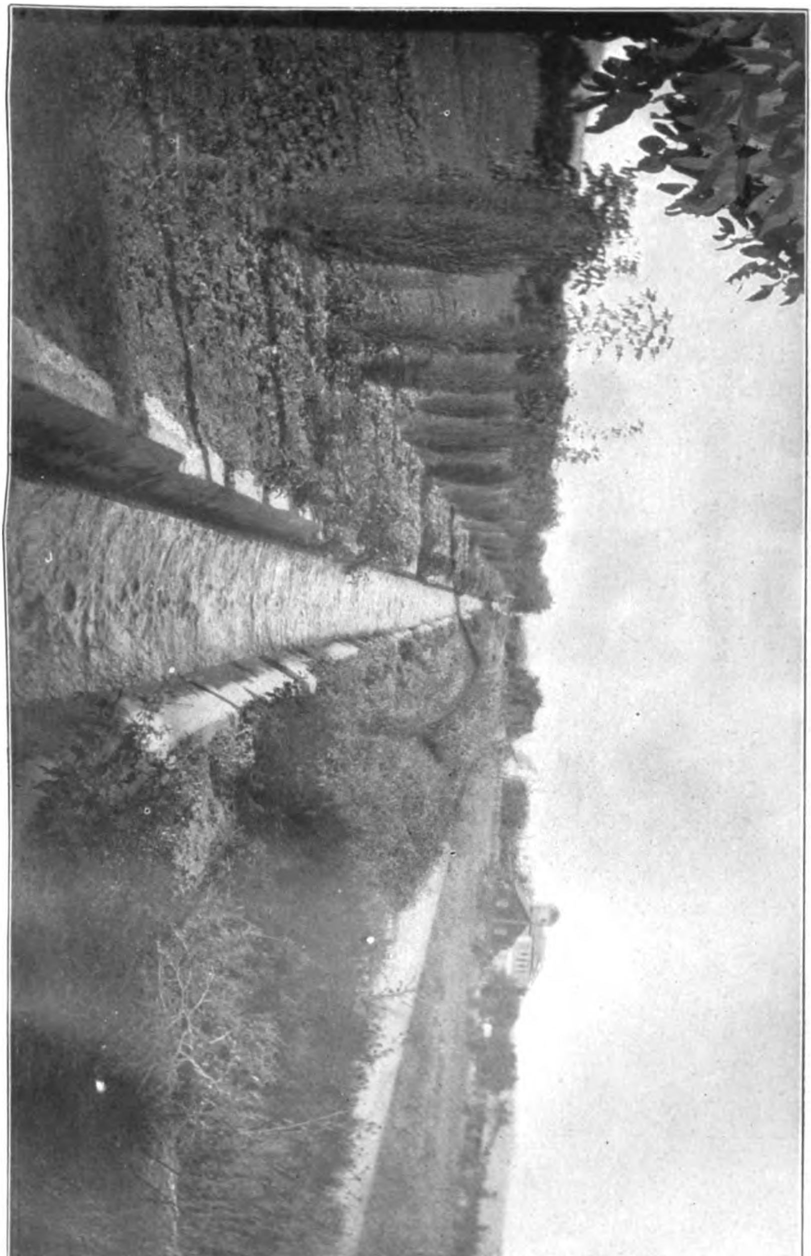
CONDITIONS OF AGRICULTURE.

Forty years ago practically all of what is now Orange County was thought valuable only for grazing land. The whole county was owned by a few men who held the titles to the original Mexican grants. Gradually it dawned upon these owners that their land was valuable for crop raising, and, with the help of irrigation, the county has undergone rapid changes. From isolated sheep camps the county has become a densely populated district, dotted with towns, and honeycombed by railroads. Santa Ana, the county seat, is a growing town of more than 5,000 inhabitants. A new court-house and high-school building have been erected recently and add materially to the general appearance of the town. Almost every denomination of the



ANAHEIM UNION CANAL WITH CEMENT SIDES AND BOTTOM.

The main canal is cemented for 2 miles along the sandy bottom land to prevent loss of water by seepage.



LATERAL DITCH, WITH CEMENT BOTTOM AND SIDES TO PREVENT LOSS OF WATER BY SEEPAGE.

Christian religion has a separate church, and there is no lack of civil, educational, and religious influences.

In the valley are the towns of Orange, Tustin, McPherson, El Modena, Olive, Anaheim, Fullerton, Gardengrove, Westminster, Smeltzer, and Buenapark. All of these towns, with the exception of Gardengrove and Westminster, are situated on the railroad. There are many other small post offices in the county, most of them being kept in connection with country stores. The county has two ports or landings where coast-line steamers touch—Anaheim Landing and Newport Beach.

The farms, or ranches, as they are called, are of all sizes, from 5-acre tracts to the San Joaquin ranch, which has 96,000 acres. The farmers are, as a rule, men of means, who have gone there to live because of the climate or have been attracted by one of the many different lines of agricultural pursuits. They have modern houses, many of which are elegant in structure and design. Every yard has a profusion of flowers and semitropical plants, which grow with but little attention. Nearly all of the country near Santa Ana, Tustin, and Orange is divided into small tracts of land of 5, 10, 15, or 20 acres, each tract having a good house and grounds. The roads are sprinkled, and a finer community or pleasanter place for residence would be hard to find. The remainder of the area is in larger tracts and is less thickly settled.

Every agricultural area in California has some special crop adapted to it. As before mentioned, Orange County is divided by elevation into two distinct agricultural areas, the uplands and swamp lands, or lands that will grow fruits and nuts and lands that will not. On the lands that will grow fruits and nuts are found English walnuts, oranges, lemons, grape fruit, grapes, apricots, peaches, peanuts, all of the smaller varieties of fruits, such as strawberries, blackberries, etc., also many different varieties of semitropical fruits, some of which will be mentioned later.

English walnuts reach a degree of perfection there that is attained in no other place in the United States, and they occupy a larger area than does any other one crop. The young trees are planted in rows 60 feet apart, so that there will be ample room for the spreading branches. Between these trees are often planted other trees, which will be cut down as the walnuts grow. Sometimes small fruits and vegetables are cultivated among the walnut trees. Walnut trees begin to bear when 5 or 6 years old and continue to do so to a great age. The trees are irrigated only during the growing season. As yet little commercial fertilizer has been used in the orchards, but stable manure has been applied with appreciable results.

The walnut is very sensitive to alkali and is one of the first trees to suffer from its presence; neither will it grow where the ground water approaches the surface, 15 feet being in all cases close enough

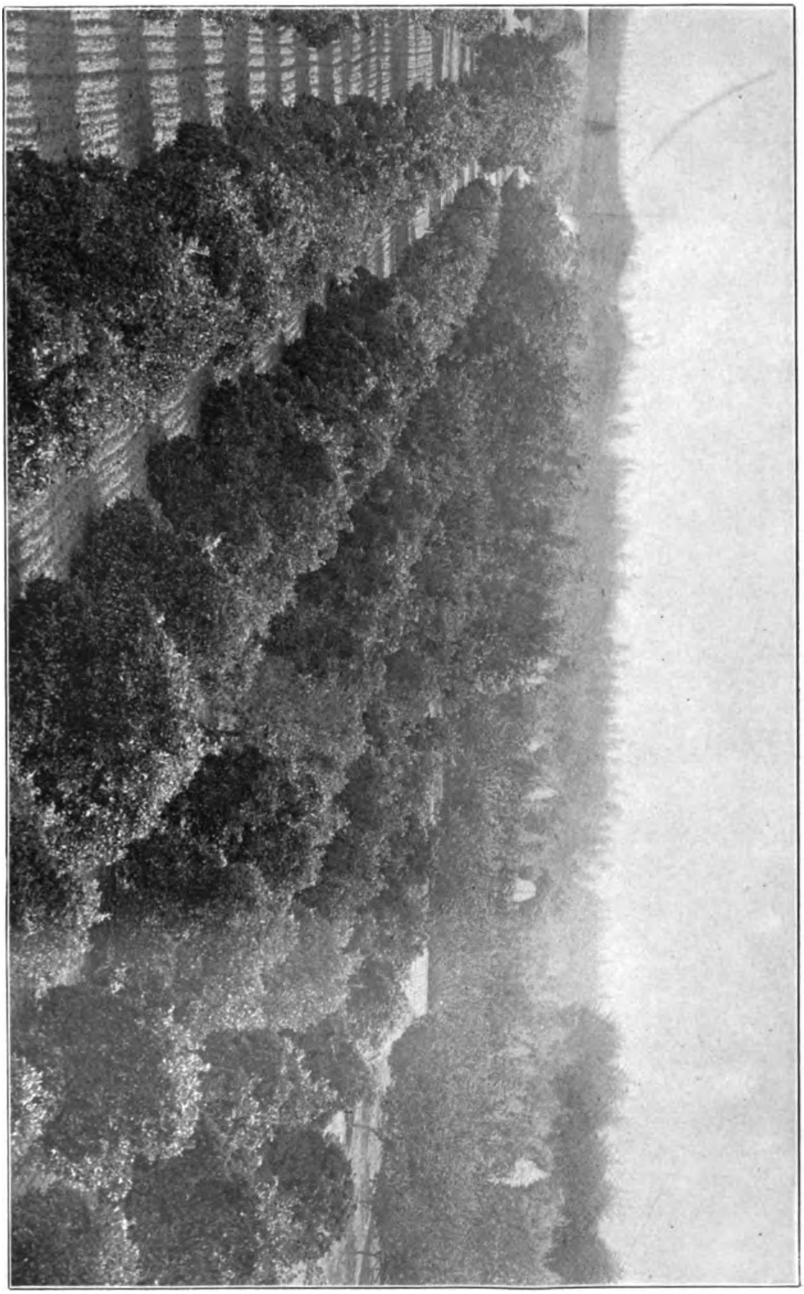
to injure it. The walnut tree sends down a long taproot, which, if it encounter any very hard substance, such as a heavy adobe subsoil it is unable to penetrate, a stunted growth results. Because of this sensitiveness great care should be exercised in the selection of land for walnut orchards. When the proper kind of soil is planted to walnuts and the trees are in good bearing condition, $1,000 per acre is about the exchange price, the price being based on the yield.

While walnut trees will grow and bear in other districts, they do not reach the degree of perfection attained here. The fogs which come in the fall nights take the place of frosts in the Eastern States, and help to break open the hulls, so that the walnuts fall from the trees ready to be gathered. On higher levels and farther from the coast, where fogs do not occur, they drop from the trees with the hull on, and, if not gathered and hulled immediately, they spoil. About the middle of September the nuts begin to ripen, the hulls split, and the walnuts continue falling to the ground until nearly the middle of November. Some growers gather them every day and others gather them every two days during this time. The nuts are picked up from the ground, placed in bags, and hauled to the ranch house, where they are washed in a revolving, wovenwire cylinder, as shown in Pl. XLV. After being dried they are again sacked, and in this condition are sold to the packing houses. Here they are dipped (immersed in a solution of chemicals) and sulphured in order to bleach them before being placed upon the market.

Recently the growers, thinking they did not receive enough for their walnuts, formed an association to regulate prices, and have almost doubled their receipts. During the past season walnuts brought to the grower 10 cents per pound for first class and 8½ cents for second class. If these prices become permanent every available acre of land in Orange County will soon be planted to walnuts. Within the last few years a disease has attacked the walnut trees, and in some localities has done much damage. It attacks the tender shoots and the nuts themselves, causing the nuts to fall from the tree before ripening. Prof. Newton B. Pearce, of the Division of Vegetable Physiology and Pathology, located at Santa Ana, is now working on this disease, and in another year, no doubt, will be able to recommend methods of controlling it.

Oranges and lemons are pretty generally grown in a small way throughout the area, but only along the highest levels are they a commercial success. The grape fruit or pomelo as yet is little known to consumers, and therefore is only raised in small amounts. The highest irrigable lands are nearly all planted to one or other of these citrus fruits, because the fogs are not so heavy on the higher levels. The same fogs that make English walnuts a success tend to make citrus fruits a failure.

ORANGE GROVE NEAR FULLERTON.



The scale is the greatest enemy of the citrus-fruit grower, and these scales thrive especially well in places where fogs occur, so the grower must be always fighting this pest. In some localities this is the greatest single item of expense. The most effective way to fight the scale is to fumigate the trees with potassium cyanide. This is done once a year, and when practiced regularly will be sufficient for relief. The cost is considerable, being about $12.50 per acre.

Northeast of Fullerton is an area known as The 'Placentia Country,' where oranges thrive and are a commercial success. This is due principally to the elevation and the consequent small amount of fog, but it is also in a measure due to the soil, which is a sandy loam underlaid by a heavy adobe. The roots of orange trees have great penetrating power and readily enter the heavy soil, where moisture is always found; therefore oranges planted on this soil require less irrigation and are able to withstand longer seasons of drought than where the subsoil is lighter. Oranges require much more water than do English walnuts, because they grow throughout the entire year. They are irrigated seven or eight times during the twelve months. Ridges are thrown up between the rows and the entire surface of the ground flooded, and as soon as the water subsides and the ground becomes dry enough it is cultivated again in order to prevent the escape of the moisture. The soil requires fertilizing, and a great deal of money is expended annually for commercial fertilizer. The trees bear so heavily that props are required to support the branches. A sort of wire hook has been invented for this purpose, which fastens to a narrow board and makes a rest for the limb. The expense for this "propping" of the trees is about the same as it is for fertilizer, and usually varies in direct proportion.

The greatest expense of an orange grower, aside from the natural expenses of irrigation and cultivation, are for fumigation, fertilization, and for propping the trees. When ripe the oranges are picked and hauled to the packing houses where they are wrapped and packed in boxes for shipment to the various distributing points.

What is true of oranges is in a general way true of lemons, except that lemons do not all ripen at the same time of year. The lemon tree is continually blooming and ripening fruit, hence there is at no one time an excessively heavy crop, and the trees need no props. Before being shipped the lemons are "cured;" that is, they are subjected to a process which will make them keep a longer time than they would if shipped immediately after being picked. Like oranges, lemons are grown principally along the highest levels. In some places they are grown on land higher than can be irrigated from the canals, water in these cases being pumped for irrigation purposes. At one time almost the whole of Orange County was planted to vineyards, but about ten years ago the vineyards of the entire county

were killed by a disease. Since that time attempts have been made to raise grapes, but only a partial success has been attained.

The other fruits mentioned in the beginning of this article are grown, but are so widely known that they need no special mention. They are grown in a commercial way, but not on so extensive a scale as oranges, lemons, and walnuts. Perhaps it would be well to make special mention of peanuts. They are usually grown between the rows in newly planted orchards and perform the twofold office of yielding a revenue and "green manuring" the soil.

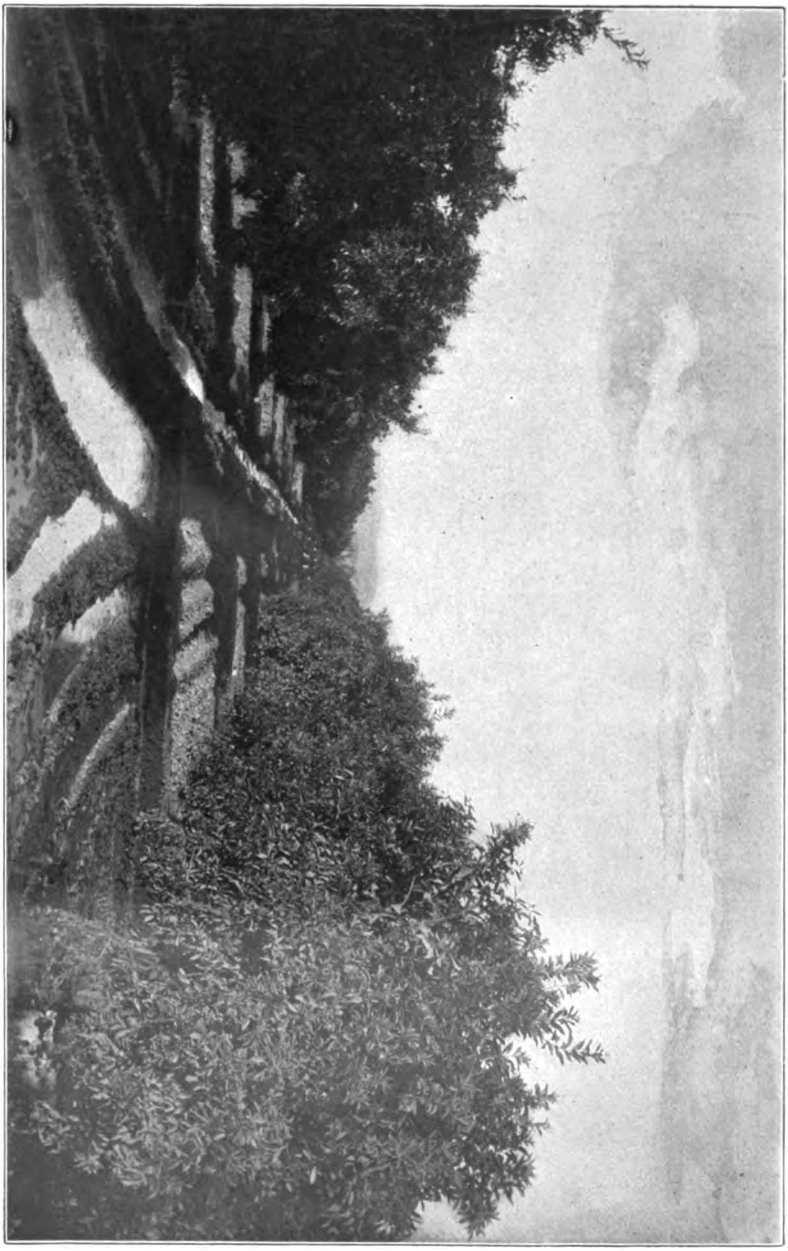
Of the many varieties of tropical and semitropical fruits introduced into southern California, the loquot is one which bids fair to gain a permanent hold. This fruit is pear-shaped, grows in clusters, and has a delicate flavor. As introduced it was not a success, but Mr. C. P. Taft has developed several varieties which are as large as small pears, and for which he receives 7 or 8 cents per pound, finding a ready sale in the markets of Los Angeles.

The swamp lands, or what is commonly known as peat lands, have been cultivated for only a few years, but even now they furnish no inconsiderable part of the exports of the county. Celery is the principal crop. It is found growing wild over the greater part of these lowlands, this wild celery being edible but much stronger flavored than the cultivated varieties. The celery seed is planted in beds, and when the plants are large enough they are transplanted in rows 4 feet apart, with the plants 9 inches or a foot apart in the rows. It is better to transplant twice, cutting the taproot off each time so that the surface roots will develop, but the common practice is to transplant but once. The plants are set in the bottom of furrows made by a plow, and as they are cultivated the earth is gradually filled in around them. Although planted on land which has to be drained because the ground water is close to the surface, the celery must be irrigated, as it requires a great deal of water. Artesian wells are put in for this purpose, and furnish an ample supply of water. A great deal of labor is necessary to keep the weeds down, most of the crop requiring hoeing at least once during growth. When the celery is large enough to harvest it is ridged, a machine designed especially for this work being used. After the celery becomes bleached it is harvested, washed, and tied up in bunches of one dozen each, which bring from 15 to 20 cents each at the station. At this rate the crop from an acre will bring from $125 to $200. This gives the grower a handsome profit over all expenditure of money and labor.

There are few modern houses in this district, most of the people living in small frame houses hurriedly constructed when the country was first settled. Many of the owners and farmers live on the higher land surrounding this area. In some parts that are subject to overflow the reason for this is obvious.

ARTESIAN WELL NEAR EDGE OF PEAT LAND.

Water used to irrigate celery. Artesian wells furnish all water for irrigation in these lowlands.



ORANGE GROVE, SHOWING METHOD OF COMBINED FURROW AND BASIN IRRIGATION COMMONLY USED.

Because of the great profit in celery growing little effort has been made toward the growing of other crops on these lowlands. Onions are grown by some and yield, on an average, 200 sacks per acre for each crop, and two crops a year may be grown. Well-decomposed peat or the surrounding Santiago silt loam is the best soil for this crop. The crop is sold at an average price of 70 cents per 100 pounds. At this price onions pay better than celery, but as the market is limited only a limited acreage will pay.

Asparagus will grow on moderately strong alkali lands; in fact, it will grow after all other edible plants have been killed. For this reason it bids fair to become a crop of value to this region. A sample of the soil from an asparagus bed on the ranch of Mr. S. J. Murdock, near Westminster, showed 0.2 per cent of alkali. Before sowing the asparagus, salt grass had been allowed to grow on this land. From two-thirds of an acre he now sells each year $100 worth of asparagus. Much of the land that is now grown up in saltbushes, salt grass, etc., in the vicinity of Westminster, Gardengrove, and Buenapark, could, with a little care, be transformed into paying fields of asparagus. There is an increasing demand for canned asparagus, as the plant loses little of its flavor when canned. If a canning factory were there, raising and canning this crop would seem to be the best solution of the alkali problem for that area.

During the first stages of cultivation the lowlands are planted to corn, potatoes, and pumpkins, but when these lands are fully "subdued" these crops are not so valuable as the ones above mentioned.

Between these lowlands and the fruit country is a belt that is partly alkaline and partly free from alkali. This belt is given over principally to dairying. On the spots where there is not an excess of alkali the land is sown to alfalfa. The alkali spots are allowed to produce what they will of native saline vegetation, which is used for pasturage. This portion of the country is quite valuable, land being worth from $40 to $100 per acre. Little labor is required here for cultivation. Alfalfa is not irrigated, the roots going deep enough to bring water from below. Butter and cheese are made in the creameries, which products find a ready sale in the markets of southern California.

The Southern Pacific Company and the Santa Fe Company each has railroads in Orange County, the Santa Fe road going on to San Diego, while the Southern Pacific stops in the county. These have branches going to nearly all the small towns, and thus furnish a rapid means for transporting the products of the county, most of which are perishable and must be placed upon the market as quickly as possible after being gathered. For short distances, as from Los Angeles to points in this county, the freight rates are high on these railroads, consequently much of the nonperishable products which are used in Los Angeles

are hauled there by teams of horses. These teams usually consist of 6, 8, or 10 horses, drawing 4 or 5 tons of material. On their return trip they bring materials from the wholesale houses in Los Angeles, these materials being used in the valley. Such bulky material as lumber, lime, etc., is usually shipped by steamers to the ports of the county, and some of the nonperishable and cheaper products of the county are shipped in this way. This method is much cheaper than the railroad rates, the principal drawback being its slowness.

INVESTIGATIONS ON THE PHYSICAL PROPERTIES OF SOILS.[1]

By LYMAN J. BRIGGS.

THE CAPILLARY MOVEMENT OF WATER IN DRY AND MOIST SOILS.

The capillary movement of water in soils is generally recognized as a subject of great economic importance, particularly in regions subject to drought; the ability of certain soils to support plant life under such conditions is usually explained on the basis of extensive capillary action, and cited as an argument in favor of this hypothesis. Comparatively nothing, however, is really known about capillary action in these soils under field conditions. There is no experimental proof that the vigorous plant development which takes place may not be due to the water supply obtained through an extensive root system, made possible by a favorable soil structure. It does not therefore follow a priori that the water supply of the plant in such cases is the result of extensive capillary action. Therefore, while we recognize capillary action as an important attribute of a soil, we do not know how much importance to assign to it, for the reason that we have very little quantitative data at our command. For reasons that will appear later, the great number of experiments which have been made on the capillary rise of water in a dry soil are of little or no value so far as representing field conditions is concerned. A method has, however, been devised by which it is believed quantitative results can be obtained which are representative of the behavior of the soil in the field. Before entering into a discussion of this subject, however, the bearing of capillary action on a number of soil problems will first be briefly considered.

Capillary action is of especial importance in relation to the position of the water table in the soil, when considered as a source of water supply for shallow-rooting plants. The importance of definite knowledge on this subject is emphasized by an extended litigation now in progress resulting from the alleged lowering of the water table underlying a valuable trucking area by the operations of a water company located in the vicinity. The method of developing irrigation water by tunnels and wells, now employed in certain regions of the

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[1] This paper embraces a brief summary of the work which has been carried on in the physical laboratory of the Division of Soils during the past year, a more complete account of which will appear in the bulletins of the Division.

West, may easily lead to similar controversies, which can be equitably adjusted only where an exact knowledge of the nature and extent of capillary action is at hand.

Even where the water table is so far below the surface that it ceases to be an economic factor, capillary action still plays an important part in bringing near the surface the water held in the soil by capillary forces. This capillary water, it must be remembered, need not necessarily come from and be in equilibrium with the ground water of the soil. While such an equilibrium would be eventually established if all application of water at the surface by rain or irrigation ceased, it is doubtful whether in a productive soil this condition is ever realized. The water supplied at the surface through occasional rains or by artificial irrigation forms a zone of saturated soil proportional in thickness to the amount of water applied. The water initially included in this zone of saturation moves downward, impelled by gravitation and the more active capillary forces in the drier soil below. The rate of the downward movement is greatly influenced by the soil structure and texture. Gravitation plays a very small part in the movement except in the case of very light soils.

At the same time that the downward movement is taking place, the water content of the soil near the surface is being lessened as the result of surface evaporation and the requirements of the crop. The maximum water content of the soil consequently is no longer found in the zone originally saturated, but at some point below this. An upward movement of water consequently begins, and as long as this supply exists within the zone of capillary action it acts as a virtual water table, although the true water table may be many feet below. We thus see again the importance of exact knowledge regarding capillary action.

Capillary action has another important bearing on soils in which an excess of soluble salts occur. It frequently happens that the ground water contains an amount of soluble material sufficient to cause a dangerous accumulation of alkali at the surface of the soil, should this water be allowed to reach the surface by capillary action and then evaporate. It is, therefore, important to prevent the water table from rising through irrigation to within the zone of capillary action, which here again should be accurately known.

The rate of capillary movement and its extent or zone of action constitute the two most important factors in capillary action. Little or no attention has heretofore been paid to the rate of capillary movement, which is in reality by far the more important factor, since it is the quantity of water delivered that is of vital importance to the plant. It therefore matters little through what distance the soil is capable of transporting moisture through capillary action if the amount transported is not sufficient for the needs of the plant. However, the soil that can transport the necessary amount through greater distances than

other soils is evidently superior, since the supply of water available for the plant is correspondingly increased.

Investigations on the extent of capillary movement of water have heretofore been practically confined to the capillary rise of water in dry soils. These results do not, however, represent the range of capillary action in the field, and they are practically without value, therefore, unless a fixed ratio can be found between the extent of capillary movement in moist and in dry soils.

Experiments to determine the limit of capillary action in a moist soil have been made in the following manner: A metal tube, provided with a gauze bottom, was filled with the soil and then saturated by immersing the lower end of the tube in water and exhausting the air from the soil by connecting a vacuum pump to the top of the tube. The tube was allowed to drain thoroughly, and a reservoir containing water was then attached to the lower end with a rubber stopper in such a manner that the end of the tube was below the surface of the water in the reservoir. The tube was next exposed, so that evaporation could take place freely from the soil surface at the upper end of the tube. If the length of the soil column is less than the limit of capillary action for that particular soil, then the water evaporating from the surface will be replaced by water drawn from the reservoir. If, however, the length of the soil column exceeded the limit of capillary action for that soil, then the water evaporated could only come from the capillary supply of the soil. It is therefore possible to determine by weighing the reservoir, when the length of the soil column is equal to the capillary limit of the soil. In case no loss of weight in the reservoir is noted, the length of the column is too great, and a short piece of the upper end of the tube is removed, and the operation repeated, as before, until a loss from the reservoir is noted.

By the method just described it was found that the capillary limit for moist sea-island cotton soil is over four and a half times greater than the capillary rise in the dry soil. The capillary limit in the moist sea-island soil was found to be 5½ feet, that is to say, no water will be supplied at the surface of the soil from the ground water through capillary action if the water table is more than 5½ feet below the surface.

Experiments to determine the capillary limit of other soils are now in progress, and it is to be hoped that other investigators may take up this work and determine the capillary limit of different soils in which they are interested. The determination of the ratio above mentioned is of interest, for the reason that the capillary rise in the dry soil is much more easily determined than the measurement of the capillary limit when the soil is moist. Unless future work shows a constant relation between the two determinations, a large number of determinations which have been made by various investigators on

the capillary rise in soils in an air-dried condition are of no value so far as determining the behavior of soils in the field.

It will be of interest to consider briefly the probable cause of the observed differences in the capillary movement of water in soils when dry and when in a moist condition. Capillary movement is determined in general by the resultant of three forces. These forces are known as surface tensions, which reside in the three bounding surfaces, since, if we have a liquid spreading over the surface of a solid, it is evident that there is present a liquid-solid, an air-liquid, and an air-solid surface. The inherent property of these surface forces is to reduce the area of their respective surfaces as much as possible. In the case of water rising into a dry soil, the capillary rise is produced by the air-solid surface force tending to contract that surface as much as possible. This force is opposed by the surface tensions of the two other surfaces, the surface area of both being increased as the air-solid surface decreases in area. We have, then, in this case the air-liquid and the liquid-solid surface tensions opposing the air-solid surface tension. The first two forces are also aided by the weight of the liquid.

In the case of water rising in a moist soil a very different state of affairs exists. The soil grains are now completely covered by a liquid film, and consequently as the water rises in the soil there is no change in the area of the liquid-solid, and there is no air-solid surface. The capillary rise is in this case, therefore, brought about entirely by the contraction of the liquid-air surface, which continues to reduce itself to the smallest area possible. This is opposed by the weight of liquid which is raised, and equilibrium results when the weight of this liquid is sufficient to balance the forces, causing the contraction of the liquid-air surface.

We thus see that there is no reason for expecting the capillary limit of a soil when moist and when in a dry condition to have the same value. In the former case we are dealing simply with one surface tension opposed simply by the weight of the liquid raised; in the dry soil, however, we are dealing with three surface tensions, two of which, combined with the weight of the liquid, are opposed to the action of the third.

INFLUENCE OF DISSOLVED SALTS ON THE CAPILLARY RISE OF SOIL WATERS.

Certain peculiar and yet characteristic distributions of the salts in alkali regions suggest that possibly the amount and nature of dissolved salts may influence to a considerable extent the capillary movement of water in soils. In order to obtain definite information on this question, which arises frequently in the consideration of the distribution of alkali, experiments were undertaken to determine the influence of dissolved salts on the capillary rise of solutions in dry

soils. These experiments were conducted in the usual manner, the air-dry soil being placed in a glass tube, provided with a fine gauze at its lower end, which was then immersed in solutions of the desired concentration. At the same time check determinations were made on the capillary rise of pure water in the same soil for the sake of comparison. The sea-island cotton soil was also used in these experiments.

A number of factors enter into the consideration of the capillary rise of a solution in a soil as compared with the capillary rise of the pure solvent. These factors appear from theoretical considerations to be opposed in general to a greater capillary rise than occurs with pure water. For example, the surface tension of the liquid-air surface of the solution is greater than for pure water, but, as we have already seen, the surface tension of the liquid-air surface in a dry soil opposes the capillary rise of the liquid. The surface tension of the solid-liquid surface also probably undergoes a change, but regarding this nothing is known directly. As we shall see, however, it is probable that this either undergoes no change or else increases in the same manner as the liquid-air surface. The increased density of the solution also tends to prevent as great a capillary rise as would occur in the case of pure water. The viscosity of the solution is also greater, but this, in the general acceptance of the term, would serve only to retard and not to diminish permanently the capillary rise.

Experiments were made with solutions of sodium chloride, sodium carbonate, and sodium sulphate of different concentrations. Without going into the details of the experiments, it may be stated that the sodium chloride and sodium sulphate solutions up to concentrations of one-half normal differ very little in their capillary rise from pure water. In the case of more concentrated solutions, however, the effect of concentration was very marked, the capillary rise of saturated solutions being only about two-thirds that observed for pure water.

These conditions can not be explained simply on the change in the density of the solutions, and one must take into consideration, also, the increased surface tension of the liquid-air surface, which in these experiments was opposing the capillary rise. It is on account of the great difference noted between pure water and concentrated salt solutions in their capillary action that we feel justified in concluding that the surface tension of the liquid-solid surface either increases or else does not materially change as the concentration of the solution increases. A marked diminution of this surface tension would tend to counteract the increased surface tension of the liquid-air surface and would not account for the differences observed.

The capillary rise for sodium carbonate solutions was much greater than for solutions of the other salts of equal concentration. This peculiarity was particularly marked in the saturated solutions. The sodium carbonate tubes were also characterized by a very gradual diminution of the moisture in the upper part of the column, so that it

was almost impossible to locate with any degree of accuracy the actual boundary between the dry and the moist soil. This was in marked contrast with the solutions of the other salts, the plane of contact between the moist and dry soil being very distinct for all concentrations.

This peculiar appearance of the sodium carbonate solution in the soil tube was so characteristic as to enable one to select readily the tubes containing solutions of this salt. It seems probable that the explanation is to be found in the fact that these alkaline solutions remove from the surface of the soil grains traces of impurities of a greasy nature which have collected there, and so furnish clean surfaces to which the solutions adhere. This peculiarity of sodium carbonate probably furnishes the explanation of the marked capillary activity which solutions of this salt frequently show under field conditions.

These experiments are not directly applicable to field conditions, any more than are experiments upon the capillary rise of water in dry soils, but in comparing the results obtained for solutions with the behavior of pure water under similar conditions we do obtain results which are applicable to field conditions when the observed differences between the behavior of water and of solutions is small. We are therefore justified in concluding that neutral salts in dilute solution have practically no influence on capillary action. Furthermore, the increased density of concentrated solutions practically counterbalances the increased surface tension, so that the maximum vertical distance through which capillary movement takes place in moist soils is not materially influenced by the concentration of the solution. For alkaline salts, however, the capillary rise is probably somewhat greater than for pure water, owing to the change in surface conditions brought about by the alkalinity of the solution.

FILTRATION OF SUSPENDED CLAY FROM SOIL SOLUTIONS.

In the soil investigations conducted by the Division of Soils in the western part of the United States frequent determinations of the approximate amount of water-soluble mineral salts present in the soils are necessary. The total amount of salts is determined approximately by measuring the electrical resistance of the saturated soil, following a method described in earlier publications of this Division. In addition to this determination, it is frequently desirable to know the relative amounts of carbonates, hydrogen-carbonates, and chlorides present in the solution. The amounts of these salts are found from volumetric determinations made in accordance with methods devised by Dr. Cameron. The solution used in these determinations is obtained by shaking a measured amount of soil in a given volume of water. Owing to the presence of suspended matter in many of these solutions, the change in color of the indicator at the end of the reac-

tion is greatly obscured. Determinations in soils containing considerable clay are particularly difficult, owing to the fact that the color of the suspended clay is in almost every case very similar to that of some one of the indicators employed. This difficulty will readily be appreciated by anyone familiar with the end-reaction color changes of phenolphthalein, methyl orange, and potassium bichromate, which are the indicators most used in the work. A still more serious difficulty lies in the fact that the suspended matter in the solutions consists in many cases of very small particles of calcium or magnesium carbonate. Consequently, when determinations are made for carbonates and hydrogen-carbonates, this suspended material goes into solution during the process of titrating, and an amount of material greatly in excess of that actually in solution in the soil waters is thus obtained. For these various reasons it was necessary to devise some method of removing the clay from the solution which should at the same time be suited to field requirements.

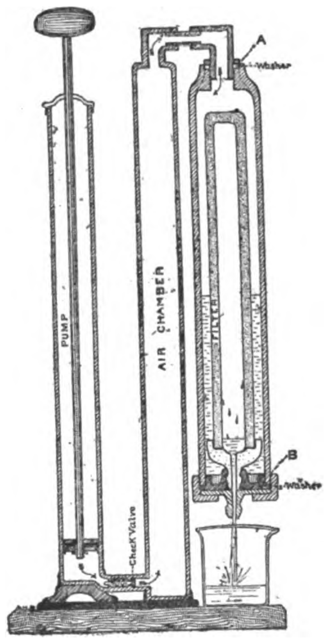

FIG. 45.—Filter, with force-pump, for the equipment of field parties.

The filtration of clay is exceedingly difficult, owing to the fineness of the particles, which were found to pass through the best of filter papers, particularly when subjected to pressure to hasten the filtration. The best of porcelain filters will, however, remove all suspended clay, and a satisfactory form of filter was finally constructed in which the Pasteur-Chamberland filter tube was employed as the separating medium. The form of the filter is shown in fig. 45. The soil solution is introduced into the filter chamber at the point A, after which pressure is applied to the liquid by means of the attached pump. An air-chamber, with a check-valve, is also provided, so that a few strokes of the pump at the beginning of the filtration is all that is necessary. This filter operates very satisfactorily, 100 c. c. of solution free from suspended material being obtained in the course of two or three minutes. It is necessary to discard the first 50 c. c. of each filtration in order to insure against the pollution of the solution by the salt remaining from preceding filtrations.

This filtering apparatus makes possible accurate determinations of the salt content of solutions which were formerly so contaminated with suspended material as to render accurate measurements extremely difficult. If the precaution regarding the discarding of the first 50 c. c. is observed, numerous tests have shown that the filtered solu-

tion is in no way different in concentration or composition from the solution before filtration.

ADSORPTION OF CARBON DIOXIDE BY SOILS.

Solid bodies possess the ability to attract and hold upon their surfaces small quantities of gases, liquids, or dissolved substances with which the solids may be in contact. This phenomenon is known as adsorption and may be described as the condensation upon the surface of the solid of a small portion of the surrounding medium. In the case of a gas, the density of the gas after adsorption is much greater on the immediate surface of the solid than at a short distance outside. In the case of a solution, the concentration of the dissolved substance is greater at the surface of the solid than in other parts of the solution. The adsorbed molecules are not free to move like the molecules in the remainder of the fluid, but are more or less permanently held on the surface of the solid by molecular force of attraction. It is not likely that the same molecules constitute the adsorbed portion of the fluid while a definite condition of equilibrium is being maintained. Undoubtedly, adsorbed molecules are continually being replaced by others striking the surface of the solid under more favorable conditions for retention, just as we have a continuous transference of molecules between a liquid and its vapor in equilibrium. By changing the concentration or the temperature, the equilibrium is temporarily destroyed, and the quantity of the substance adsorbed is changed to meet the new conditions imposed.

The phenomenon of adsorption has a practical bearing of great importance and significance in many soil problems, such as the reclaiming of lands containing an excess of soluble salts, and particularly in the theory of fertilizers, in which connection it furnishes a rational explanation of the differences observed in the rate at which various substances are leached from the soil.

The adsorption of carbon dioxide is of practical interest from two different standpoints. First, it promises to have an important bearing on the cause and treatment of the part of the so-called "acid" soils, which in many cases appear to be simply the result of the adsorbed carbon dioxide. The amount of this gas adsorbed by soils, even under ordinary atmospheric conditions, is relatively very great. Investigations in this laboratory have shown that the amount of carbon dioxide adsorbed on the surface of a pure quartz sand in equilibrium with the partial pressure of carbon dioxide in the atmosphere is 200 times the amount of carbon dioxide contained in the air filling the interstitial spaces of the sand. According to Johnson (How Crops Feed), the carbon dioxide in the soil atmosphere varies in amount from 30 to 200 times that found in the free atmosphere. Consequently, if the above proportion holds for the different partial pressures, we would have adsorbed on the surface of the quartz

grains amounts of carbon dioxide varying from 6,000 to 40,000 times that found in the interstitial spaces if filled with atmospheric air. With loam or clay soils the amount of carbon dioxide adsorbed would be greatly increased, since for the same solid the adsorption is directly proportional to the amount of surface. Different solids appear to adsorb the same substance to a different extent. Humus appears to be very active in this respect, but a quantitative comparison is not possible on account of the uncertainty regarding the surface area exposed. Further investigations on the adsorption of both carbon dioxide and dissolved salts are now in progress.

The amount of adsorbed carbon dioxide has an important bearing on the relative amounts of sodium carbonate and sodium hydrogen-carbonate coexisting in the soil solution. The marked difference in the toxic action of these salts renders a knowledge of their equilibrium under various conditions of great importance. This subject has been investigated conjointly with Dr. Cameron, and it has been found that the partial pressure of the carbon dioxide exerts a marked influence upon the relative amounts of the two salts. A slight increase in the partial pressure of the carbon dioxide in a solution in equilibrium with the atmosphere has the effect of increasing the amount of sodium hydrogen carbonate. In such cases the supply of adsorbed carbon dioxide is of material value in preventing, or at least delaying, the formation of sodium carbonate.

Furthermore, the very important part played by carbon dioxide in increasing the solubility of certain soil constituents lends additional weight to the importance of this great potential supply adsorbed on the surface of the soil grains. The subject is unquestionably one of great import and worthy of a thorough investigation in all its phases.

APPLICATION OF THE THEORY OF SOLUTION TO THE STUDY OF SOILS.[1]

By FRANK K. CAMERON.

INTRODUCTION.

The study of soils has led to a broad classification of the problems presented as pertaining on the one hand to humid regions and on the other to arid regions. If one neglects contributing factors to their agricultural value, such as climatology, etc., and considers the soils in themselves, it will be seen that the differences between the soils of the arid regions and those of humid regions are of degree rather than of kind. The soils of the arid regions frequently contain quantities of salts readily soluble in water, or "alkali;" but these same salts, though perhaps in quantities practically negligible, are to be found in other soils. It might be said that the physical and chemical problems presented by any one soil are problems for all other soils, although not necessarily of the same immediate practical importance. The soils of arid regions, on account of their large content of quite soluble components, lend themselves more readily in general to chemical and physical investigations than do the soils of humid regions. It is natural and logical, therefore, that alkali soils should first receive attention, and the ideas and methods thus developed should then be applied to the more difficult investigation of the soils of humid regions. For obvious reasons this has not been the historical order of development in soil studies. It is in this sequence, however, that certain lines of investigation have been and are developing in the laboratory of the Division of Soils. In these developments the hypothesis of electrolytic dissociation in aqueous solution has been the guiding principle. Some of the ways in which the theory of solution has thrown light on soil problems will be pointed out in the following pages. The experimental investigations, of which brief sketches are given in this paper, were undertaken to elucidate difficulties encountered in the field, or to follow up clues which the experiments themselves suggested.

NATURE AND FUNCTION OF SOIL SOLUTIONS.[2]

If a soil be considered in a comprehensive way as a material system it will be seen that its components appear in three different states of physical aggregation or phases—the solid, liquid, and gaseous.

[1] The first paper on this subject (by the same writer) appeared in Report No. 64, U. S. Dept. Agr., Field Operations of the Division of Soils.

[2] A more detailed discussion of this subject has been published in Bulletin 17 of the Division of Soils.

The solid components are for the most part inorganic, and to a lesser extent, organic or material derived from the decomposition of substances associated with organized life processes and containing the element carbon as an essential constituent.

The liquid phase consists of a water solution of the various soil components which come into contact with the solution; for to some extent at least all other components of the soil are soluble in the soil water.

The gaseous phase *in the soil* is like the air above the soil in containing the same components; but unlike it in that the relative amounts of these components are very different. Thus, the proportion of carbon dioxide in the soil atmosphere is always greater than in the air, and frequently very much greater. This will be shown later to be a very important factor in soil phenomena.

In considering the relation of the soil to plant growth the liquid phase or soil solution is of the first importance, for it is from the soil solution that the plant roots draw the mineral nutrients essential to their growth. The logical method then of attacking soil problems is to consider the function and nature of soil solutions, and in what way and to what extent they may be modified by the materials in the solid phase and the gaseous phase which come in contact with the solutions. For the most part the mineral components, and many of the organic components of the solid phase which come into contact with the soil water, belong to that class of chemical compounds known as electrolytes[1]—that is to say, that on going into solution they partially break up or dissociate, yielding ions which are elements or aggregations of elements bearing or in some way associated with electrical charges. A detailed description of these dissociation phenomena has been given in the former report of the Division. It is not possible to repeat it here, but certain general conclusions will be restated as the basis of the following discussions.

It has been shown that when two electrolytes which yield a common ion are brought into solution, the solubilities of both electrolytes are thereby decreased; but when the electrolytes do not yield a common ion, the solubilities of both electrolytes are increased with the formation to some extent of two more salts. These mutual solubility effects are most striking when one of the electrolytes is but slightly soluble itself in pure water. For instance, if a solution containing the soluble salt sodium nitrate be brought in contact with the very slightly soluble salt iron phosphate, which there is good reason to believe is a quite common constituent of soils, the solubility of the

[1] So called because they impart to the solution the power to conduct an electrical current. The classification is practically confined to acids, bases, or salts, which last may be considered as formed by the combination of acids with bases.

latter is considerably increased, the soluble salt sodium phosphate being formed to some extent. The phosphoric acid is thus rendered much more readily available to plants. From this point of view, it is quite easy to see how the addition of a mineral fertilizer will enable crops to obtain and take up from the soil a constituent which they could not before obtain and which is not present in the fertilizer itself. On the other hand, the addition of a fertilizer, itself harmless, may bring about a reaction with some soil component to form a harmful substance.

Thus the addition of a mineral fertilizer to a soil serves at least two purposes. It may in itself add a desirable plant food, and by its action on the soil components it may render them more soluble, putting some desirable constituent in a more available form than when locked up in a comparatively insoluble form. In this view, fertilizing is an assistance to the natural process of weathering, inasmuch as it is furthering the breaking down of the complex mineral components of the soil.

The extent to which an electrolyte will dissociate and form ions is a characteristic property, and varies much with different electrolytes. Those electrolytes which dissociate much and are therefore very active chemically are called "strong," in contradistinction to those which only dissociate to a small extent, are consequently less active, and are called "weak." Thus, the common acids, such as hydrochloric acid or sulphuric acid, the common bases potassium hydrate, sodium hydrate, or calcium hydrate, and the salts which these substances would form with one another are strong electrolytes; but carbonic acid and silicic acid are weak electrolytes. Water itself is a very weak electrolyte, containing not more than 1 gram of hydrogen ions in 12,000,000 liters of water.

The mineral components of the soil almost entirely and the organic components to a large extent are salts. In the major part of these salts they are composed of a strong base united with a weak acid; much less frequently there is a weak base united with a stronger acid. In all cases where there is a marked difference in the strength of the base and the acid which are combined to form the salt, the action of the water upon the salt is marked. For the water itself is a weak electrolyte, and by its action on the salt there is formed either a strong base or a strong acid, which, in consequence, predominates over the other weaker electrolytes, imparting its characteristics to the solution. Thus, if one take a potash feldspar, a common component of soils, which contains the strong bases potassium and calcium combined with a weak complex silicic acid, grind it to a powder so that a large surface can be exposed to the action of the solvent, and shake it up for a few minutes with water, the addition of phenolphthalein will show a marked alkaline reaction. Here the water has reacted with the salt to form the strong bases potassium hydrate and calcium

hydrate and the weak complex silicic acid. If now the potassium and the calcium be removed by leaching or taken up by the plants, etc., the weak acid will be left behind, being also much less soluble. It is characteristic of such acids that they are of themselves unstable compounds and generally break down when the base is removed, forming at the same time some form of silica—amorphous or as quartz.

The action of water upon electrolytes containing a weak base combined with a stronger acid or a strong base with a weaker acid is known as hydrolysis, and is very common, especially in nature. Its rôle in weathering processes does not seem to have received the consideration which it merits. Its importance is constantly becoming more evident as the study of these processes is continued. Some examples of the way in which these views throw light upon soil problems will be cited.

RÔLE OF IRON IN THE SOIL.

Iron is a common constituent in many rock-forming minerals. Sometimes it appears as an acid-forming element, partially replacing aluminum in complex silicic acids. Sometimes it appears as a base-forming element, partially replacing lime or magnesium in the mineral. However, it is always "weak" in both its acid-forming and base-forming properties, and consequently on the solution of the mineral in which it occurs it is considerably hydrolized, forming the very slightly soluble ferric hydrate[1] which is precipitated. Again, iron sulphides are frequently found in the rocks. By surface oxidation these substances are first converted into the soluble ferrous sulphate and leached away from the parent material, and thus, because the weak base iron is combined with the strong sulphuric acid, it is hydrolized with the formation of iron hydrate even in the presence of an excess of the strong acid.

It will be observed, therefore, that the general tendency in the weathering of iron-bearing minerals is the formation of the hydrate of iron, a very insoluble substance in pure water; but the water of the soil always contains in solution, among other things, considerable amounts of carbonic acid formed by the combination of dissolved carbon dioxide with some of the water itself. The amount of this carbonic acid present depends upon the amount of carbon dioxide dissolved, and this in turn will depend upon the proportion of carbon dioxide in the soil atmosphere, for gases do not appear to have a definite solubility in liquids, as do solids, for instance, but are miscible with the liquid in all proportions, depending in any given case upon the partial pressure which that particular gas is exerting in the gaseous phase or atmosphere in contact with the solution. As will be pointed out by Mr. Briggs elsewhere in this report, and as has been

[1] It is very improbable that ferrous hydrate can ever exist in the soil, since there is always enough oxygen in the soil atmosphere to convert it to the ferric condition.

known since the measurements of Boussingault and Lewy, the amount of carbon dioxide in the soil atmosphere may be very large, and is always larger than in ordinary atmospheric air.

Iron hydrate in contact with such water is somewhat more soluble, owing to the formation of carbonates of iron; and the extent to which these carbonates of iron would be formed would depend upon the amount of carbonic acid in the solution. In this manner iron would be dissolved and transported through the soil; but if the solution reached a point in the soil where carbon dioxide can escape from the solution and enter the gaseous phase, it will do so. There will be a disturbance of the equilibrium, the unstable carbonates of iron will give off more or less of its carbonic acid, and hydrate of iron and carbonated hydrate will be precipitated. This may be brought about, for instance, by the solution coming to an ærated place in the soil and the proportion of carbon dioxide in the soil atmosphere being lowered, or by going from a fine-textured soil, in which the interstitial spaces are completely filled by the solution, to a coarser-textured region, where the spaces are larger, giving room for the escape of carbonic acid from the solution to the gaseous phase. Such cases have been pretty definitely followed in the studies of the Division. In the precipitation of the hydrate or carbonated hydrate of iron it frequently cements together the soil grains, making the ironstone hardpan or conglomerate so frequently found under the surface of our fields.

It is generally believed, and with a great probability, that the small amount of phosphoric acid in the soil, which is so necessary to plant growth, is mainly held in combination with iron as a very insoluble iron phosphate. In this case not only is the substance itself very slightly soluble, but it is composed of a weak base united with a rather weak acid, so there would be very little dissociation and hydrolysis. If, however, another strong electrolyte, such as potassium chloride, be added, the two substances would necessarily react with one another, forming potassium phosphate and iron chloride (both soluble substances), and to this extent the iron phosphate can be regarded as being made more soluble. The details of the reaction can not be followed here, but it will suffice to point out a possible explanation for the fact frequently observed in practice that the addition of a potash fertilizer very frequently enables the plant to take up much-increased amounts of phosphoric acid from the soil. Moreover, from the hydrolysis of the ferric chloride it is probable that there would be some free hydrochloric acid formed, which would react with the complicated weak silicates to form chlorides of potash and other bases, so that actually more potash would become available than was actually put upon the soil. This view is in accord with field observations. The rôle of iron in conserving the valuable plant food, phosphoric acid, preventing it from being leached away, and in

holding it in such form that it can be obtained gradually for plant nutrition, can not be overestimated.

RÔLE OF CALCIUM IN THE SOIL.

Calcium when applied to the soil, either as quicklime, slacked lime, or the carbonate, is soon converted to the latter form by the action of carbonic acid; and the advantages sometimes supposed to be derived from adding it in the forms first mentioned are probably mechanical or physical, possibly as giving the resulting carbonate a loose pulverent form, and thus exposing a larger surface to the action of the soil solution than would the more compact carbonate in the form of limestone. It has been shown in the laboratory of the Division that the solution resulting from the contact of the soil waters with the material would contain practically all the lime in the form of the bicarbonate, in which a strong base is in combination with a very weak acid. By its action on iron phosphate it would be expected that some calcium phosphate would be formed, a substance rather more soluble than the iron salts; but it has been believed that its principal rôle, aside from itself furnishing nutriment for plant growth, is to liberate potassium from the potassium-bearing minerals in the soil. That it can do so, is of course evident from what has been said above, for by its action upon a potassium silicate, for example, some potassium carbonate would be formed, and at the same time an equivalent amount of calcium silicate.

The calcium salts being of quite limited solubility, there is no danger to be apprehended from the addition of quite large amounts of lime to the soil, so that the process can be kept up continuously, as the small amounts of potassium liberated at a time are taken up by the plants or leached away by the soil waters.

SOME POSSIBLE FUNCTIONS OF HYDROUS SILICATES.

It has long been held that this action of lime in liberating potassium was dependent upon the existence in the soil of certain hydrous silicates, possibly zeolites. This theory has had strong opposition, based mainly on the fact that no crystallized zeolites as such have ever been identified in the soil. On the other hand, there does not appear to be any good reason for supposing that zeolites may not be in the soil, though not in well-defined crystalline form, for all the necessary constituents are present, and it is not easy to see why synthetical or formative processes may not be going on in the soil as well as destructive ones. The discussion in this shape is mainly academic, however, as it is evident that the action of the lime on any potassium-bearing silicate would be the same in kind, if not in degree, to its action on a zeolite. From another point of view, however, the subject seems to have a possible real interest for agriculture. Tammann has shown that many of these hydrous silicates or zeolites do not hold their water

in the form of definite chemical compounds, but really in the form of a "solid solution" of the water in the mineral; that is to say, they will gradually take up more water or lose it, depending upon the partial pressure of the water vapor in the gaseous phase in contact with the mineral or solid solution and upon the temperature, so that it seems possible that such minerals may exist in the soil, one of their functions being to store up water and then to gradually give it up again as the soil atmosphere becomes dried out. Again, the researches of Friedel have shown that in the zeolites the water may be more or less completely replaced by ammonia, so that possibly these substances may have a use in holding nitrogen in the form of ammonia in the soil.

RÔLE OF CARBON DIOXIDE IN THE SOIL.

The researches of Boussingault and Lewy early showed that the proportion of carbon dioxide in the soil atmosphere was often very large and practically always larger than in the air above the soil. The researches of Bunsen and others, and more especially Mr. Briggs, of the Division of Soils, have given an explanation of the fact. It is of the utmost importance in a consideration of the chemical phenomena involved in the soil. Carbon dioxide dissolved in water reacts with it to some extent to form the weak electrolyte carbonic acid. When the weak acid comes in contact with the weak mineral electrolytes of the soil the solubility of the latter will be somewhat increased, as would be the case when any two electrolytes not having an ion in common are brought together in the presence of water. But there is another way to look at this same phenomenon. With any given electrolyte of the soil and carbonic acid there will be presented the case of a base or bases in the presence of two acids and not in sufficient amount to satisfy both. A number of interesting investigations on analogous cases have taught us that there will in consequence be a distribution of the base or bases between the two acids, this distribution being a function of the "strength" or ionizing power of the acids involved. As the carbonates or bicarbonates of the bases are generally more soluble than the complex silicates in the soil, the action of the carbonic acid will result in bringing the bases into a more soluble form, that is, into a condition more favorable for plant nutrition. It is obviously a wise provision of nature that carbonic acid is a weak electrolyte, for otherwise the bases so desirable for plant nutrition would be rapidly taken from the soil and leached out. It is important to notice also that methods for the improvement of the texture of the soil also improve the capacity for keeping a constant but not excessive supply of carbonic acid on hand to assist in the digestion of the soil components, making their constituents readily available to the plant.

From what has been said in some of the foregoing paragraphs, it might be inferred that, as a result of the hydrolytic action of the water

on the soil components, the soil solutions would be alkaline, whereas they are almost invariably slightly acid. This is unquestionably in the vast majority of cases due to the excess of carbonic acid in the soil solution. Even in the cases where the soil is boggy and "sour," this sourness or acidity is probably due in large measure to excessive quantities of carbon dioxide, for such conditions are just the ones best suited to the formation and retention of large quantities of this substance, which thus becomes a curse instead of a beneficent agent.

ORGANIC MATTER IN THE SOIL.

Aside from its physical properties in improving texture, etc., the organic matter in the soil has important chemical functions. It is the means of returning to the soil practically all the elements which have been taken from it by cropping; and by the process of decay, sometimes involving the activities of organisms, ferments, etc., readily putting it in a form most available for plant growth. By these various processes of decay many acids are formed, notably, it is believed, certain amido acids, which are themselves subject to the further destructive action of micro-organisms. But inasmuch as they are acids they all play their parts in assisting and promoting the decomposition of the mineral components of the soil in the manner indicated when speaking of carbonic acid.

ADSORPTION BY SOILS.

It has been generally recognized, since the classic researches of Liebig and of Way, among others, that finely divided solids such as some soils, boneblack, etc., have the remarkable property of separating from the solvent and holding back certain substances when solutions of the substances are filtered through them; but more remarkable still, they actually seem sometimes to show a selective adsorption toward the different parts of a chemical individual and to take out certain constituents of an electrolyte and allow the rest to pass through with the solvent. It has long been believed that ammonia can be partially removed from ammonium salts in this way, the resulting solution thus becoming acid. Recently Œchsner de Conick has shown that a solution of iron chloride, for instance, when passed through animal charcoal leaves behind the iron, the chlorine coming through practically quantitatively in the form of hydrochloric acid. It will be noted that substances in which this phenomenon has been observed consist of a weak base combined with a stronger acid (just those substances in which hydrolysis would be expected), and it seems not improbable that the explanation is that hydrolysis takes place, the solution then being one of the hydrolyzed products, and the phenomenon becomes one of the selective holding back, or adsorption, of one of the hydrolized products, or a mechanical retention of it. Very little

definite data is available for a discussion of this subject, and it is intended to give it further attention in the laboratory of the Division.

EQUILIBRIUM BETWEEN CARBONATES AND BICARBONATES IN AQUEOUS SOLUTIONS.[1]

The considerations advanced in the preceding chapter hold for all soils in general. In arid regions, with their large accumulations of readily soluble salts or "alkali" in the soils, the alkali becomes of first importance in a chemical study of the soil. Of these readily soluble components of the soil, the carbonates hold a unique place on account of their exceptionally noxious influence upon vegetation and their action upon the other soil components. As has been stated above, the soil atmosphere always contains at least as much carbon dioxide as atmospheric air does, and generally more; so that the soil solutions must always contain some carbonic acid and, if carbonic acid be present, bicarbonates or hydrogen carbonates as well. These latter substances, the hydrogen carbonates, do not appear to be as noxious to vegetation as the normal carbonate. Investigation in the laboratory of the Division has shown that certain plants can withstand at least six times as much sodium bicarbonate as they can of the normal carbonate. It is of importance, therefore, in studying "black alkali" to be able to distinguish between the normal carbonate and the hydrogen carbonate or bicarbonate in the soil. A method which will be described at another place in this report has been devised, so that this can be readily done; but the results obtained in the field were apparently so astonishing as to the proportions observed between the normal carbonate and hydrogen carbonate in soil solutions, river and canal waters, etc., that the subject was referred to the laboratory for investigation.

The most striking observations probably in this connection were made in the Sevier Valley, Utah. It was found that the ratio of bicarbonates to carbonates was very large in solutions in some of the soils. Some solutions of these soils, when freshly prepared, showed but the faintest trace of color with phenolphthalein. But on standing awhile they gave a very marked alkaline reaction. Some pools in the soil were examined soon after they were formed and showed but little alkaline reaction, although containing considerable amount of bicarbonates; but after standing awhile they became markedly alkaline. A careful examination of river and canal waters, contaminated by seepage waters, frequently showed considerable quantities of bicarbonates, but no normal carbonates at points just below where the seepage enters them; but some miles lower down marked quantities of normal carbonates were found to be present.

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[1] A detailed description of an experimental investigation on this subject by Lyman J. Briggs and Frank K. Cameron will appear at an early date in another publication of the Division of Soils.

The amount of carbon dioxide in the atmosphere in different soils, or in the same soil under different conditions, is probably a widely varying quantity, while that in ordinary air is approximately constant. Therefore it was deemed advisable to have data for solutions in equilibrium with ordinary air rather than for an atmosphere with some arbitrary amount of carbon dioxide in it. The conditions chosen with respect to the carbon dioxide were those in which the solution would have the maximum proportion of normal carbonate which could occur in nature, and this information is in itself one of the most important results derived from the investigation.

Solutions of different concentration with respect to the base were prepared and brought to equilibrium with the air, being kept meanwhile at a constant temperature. The amount of normal carbonate and hydrogen carbonate present were then determined. The results were charted and by interpolation on the curves it is a simple matter to determine the proportion of normal carbonate for any given concentration. A brief description of some of the results obtained follows.

SODIUM SALTS.

It was found that in a solution of any given concentration with respect to the amount of sodium present the proportion of the sodium combined as normal carbonate increased with the rise of temperature, until at 100° C. all the sodium was in the form of normal carbonate at practically all concentrations.

In solutions at any constant temperature below 100° C. and containing less than 9 grams of sodium per liter the proportion of normal carbonate decreases rapidly until as infinite dilution is approached all the base is combined as hydrogen carbonate. In solutions containing more than 9 grams per liter of sodium the proportion of normal carbonate increases very gradually as the total concentration increases. For solutions at 25° C. and in equilibrium with the air the following data were obtained:

The sodium is equally distributed between the two salts, normal carbonate and hydrogen carbonate, in a solution containing about 2.9 grams sodium per liter. In a solution containing 9 grams sodium per liter about 63 per cent of the base is in the form of normal carbonate, and the proportion rises only to about 65 per cent when the solution contains 45 grams of sodium per liter.

There are equal weights of sodium carbonate and sodium hydrogen carbonate in a solution containing about 21 grams per liter of the two salts together, that is, about a 2 per cent solution. In a solution containing 56.5 grams of both salts (about a 6 per cent solution) there is about 30 grams per liter of normal carbonate and about 26.5 grams per liter of the hydrogen carbonate, the proportion of normal carbonate having risen to nearly 53 per cent and containing about 64 per cent of the total sodium in the solution.

POTASSIUM SALTS.

In the case of the potassium salts the results obtained were of the same general nature as those obtained with the sodium salts, but the rate of increase of the proportion of normal carbonate with the total increase of concentration does not show as great a change at some point as is the case with the solutions of sodium salts; that is to say, the transition from the steeper to the flatter part of the curve is not so abrupt. At 25° C. in a solution containing 15.25 grams potassium per liter, 77.5 per cent of the base is combined as normal carbonate; the proportion rises to 84 per cent when there are 21.4 grams per liter, and to 91.4 per cent with 73 grams per liter of potassium in the solution. From this point, however, it drops slightly, and only 88.5 per cent is combined as normal carbonate when the solution contains 144 grams per liter of potassium. The dropping off of the percentage of normal carbonates at high concentrations was observed in the case of the sodium salts also, but was not so well marked as with the potassium salts.

The explanation of the phenomena observed in the Sevier Valley is apparent from the results recorded above. The total amounts of carbonates in the soils there are never very large, for there is fairly good natural drainage, and, as will be seen from the foregoing paragraphs, the proportion of normal carbonates decreases with dilution, and below a certain point, which would correspond, approximately, to 0.25 per cent of the soil, this decrease is rapid. But the proportion of hydrogen carbonate must be still further increased in the soil by the fact that soil atmosphere, and therefore soil solutions, contain much more carbon dioxide than ordinary air and solutions in equilibrium with it. Therefore, soil solutions or seepage waters fresh from the soil and containing hydrogen carbonates, on coming to equilibrium with the air will give up some carbon dioxide, and a part of the hydrogen carbonate will invert to the normal carbonate, giving to the solution the characteristic alkaline reaction.

It is worth while to point out that the effect of underdrainage of soils containing black alkali is not only to lessen the total amount of salt present, but at the same time to convert the specially noxious carbonates to the much less harmful hydrogen carbonates.

CALCIUM SALTS.

The solubility of calcium carbonate in pure water (free from dissolved carbon dioxide or carbonic acid) was found by Schloesing[1] to be 0.0131 grams per liter when at a temperature of 16° C. The addition of dissolved carbon dioxide to the solution with the formation of carbonic acid apparently raises the solubility of the lime carbonate by the formation of the more soluble hydrogen carbonate. Tread-

[1] Compt. rend., 74, 1552 (1872).

well and Reuter[1] found that when the solution was in contact with an atmosphere of carbon dioxide at a pressure equal to 760 millimeters of mercury and at 15° C., the solubility was increased until there was the equivalent of 1.156 grams per liter of calcium carbonate in the solution. The solubility of the substance is nearly ninety times what it is in pure water.

The two solubilities just quoted may be regarded as the extreme limits which are never realized with soil solutions. The researches of Bodländer have shown that in the first case practically all the calcium must have been in the solution as free calcium ions and that about 80 per cent of the salt was hydrolyzed, that is, to all intents and purposes, present as dissociated calcium hydrate. In the experiment of Treadwell and Reuter, which has been quoted, all the calcium must have been present as the hydrogen carbonate, and from the nature of the case there could have been no hydrolysis. From Schloesing's determinations made at 16° C. it would appear that the solubility in a solution in equilibrium with the atmospheric air would be about 0.0746 grams per liter reckoned as normal carbonate, that is, the solubility is about six times that in pure water.

To determine the ratio of normal carbonate to hydrogen carbonate the experiment was made of shaking up some pure precipitated calcium carbonate with two portions of distilled water, one of which had been previously boiled some time and then cooled to ordinary temperature. A drop of alcoholic phenolphthalein solution was added to each. Instantly the solution prepared with water which had been boiled gave an intense red color, showing much hydrolysis, while the solution made with the water which had not been boiled showed no color. The flasks containing the two solutions were appropriately connected and air passed through them in alternate directions for several days until equilibrium had been reached. Determinations made with both solutions gave fairly concordant results, and it was conclusively shown that certainly not more than 3 per cent of the dissolved calcium could be present as the normal salt. A large number of other observations make it probable that in solutions in equilibrium with the air practically all the calcium is combined as the hydrogen carbonate; that is to say, that in solutions in nature one practically never has to deal with calcium normal carbonate but always and entirely with the hydrogen carbonate. This means that calcium hydrogen carbonate is a fairly stable compound. Treadwell and Reuter found in their experiments that by gradually reducing the proportion of carbon dioxide in the gaseous phase in contact with the solution until it vanished, the solution would then contain 0.385 gram per liter of the hydrogen carbonate, equivalent to 0.23 gram per liter of the normal carbonate, or about 18 times the amount which Schloesing found soluble in pure water, or 3 times the amount which will be

[1] Zeit. für anorg. Chem., 17, 178 (1898).

taken up by water in equilibrium with air under normal conditions. Experience has shown that while this relatively large amount of salt can be held in solution quite persistently, long standing or agitation will gradually cause a precipitation of the excess and the solution will come to normal concentration. The facts just presented will account for the fact that spring water or seepage waters fresh from the soil with its large content of carbon dioxide will frequently carry unusually large amounts of calcium, a part of which they will give up, but with seemingly great reluctance.

MAGNESIUM SALTS.

All investigators who have worked with solutions of magnesium carbonate near the saturation point have found great difficulty in getting concordant results. Engel[1] found the solubility of the normal carbonate in pure water at 12° C. to be 0.970 gram per liter. Treadwell and Reuter found that at 15° C. it was about 0.627 gram per liter. These latter investigators found that in contact with an atmosphere of carbon dioxide at a pressure of one atmosphere the solution contained 12.105 grams per liter of the hydrogen carbonate, equivalent to 6.977 grams of the normal carbonate. Magnesium hydrogen carbonate, unlike the corresponding calcium salt, was found to be a very unstable compound and could only exist in the presence of a considerable excess of carbon dioxide.

The discrepancies mentioned above seem to be due to the formation in solutions near the saturation point of complex compounds which may dissociate with the formation of very complex ions and hydroxyl ions. This would account for the fact that solutions of magnesium carbonate are so strongly alkaline. It is tantamount to saying that there is much hydrolysis; but at greater dilution it is improbable that these complex compounds have any actual existence, and, to all intents and purposes at least, the solution may be considered as containing only the salts, normal magnesium carbonate and magnesium hydrogen carbonate. Some determinations were made of the distribution of the base between the two salts in solution at 30° C.

In a solution containing 0.0241 gram of magnesium per liter the base was equally distributed between normal carbonate and hydrogen carbonate. The sum of the two salts was 0.1144 gram per liter, of which 0.0418 gram, or 36.5 per cent, was the normal carbonate and 0.0726 gram, or 63.5 per cent, was hydrogen carbonate.

In a solution containing 0.1609 gram magnesium per liter 53.9 per cent was combined as normal carbonate. The sum of the two salts per liter was 0.7479 gram, of which 0.3012, or 40.3 per cent, was normal carbonate and 0.14467 gram, or 59.7 per cent, was hydrogen carbonate. From these results, it appears that in all solutions with which one has to deal about half of the magnesium is in the form of

[1] Compt. rend. **100**, 144 (1885); Ann. Chem. et Phys., 6, 13, 349 (1888).

normal carbonate. Solutions of magnesium salts are therefore in strong contrast to solutions of calcium salts, in which practically all the base is combined as hydrogen carbonate.

The conditions seem to be somewhat different if the solution of magnesium carbonate is in contact with the salt in the solid phase. Solid magnesium carbonate was suspended in water and air passed through the solution continuously for twenty-nine days; it then contained 0.1530 gram per liter of dissolved magnesium, of which 29 per cent was combined as normal carbonate. Air was again passed through the solution for seventeen more days, when it contained 0.1837 gram magnesium per liter, of which 29.5 per cent was in the form of normal carbonate. After standing for fifty-four days longer the solution contained 0.1808 gram per liter of magnesium, but nearly 34 per cent was combined in the form of normal carbonate. Therefore it appears that the contact of the substance in the solid phase actually lowers the proportion of normal carbonate in solutions of the magnesium salts. It is evident, also, that the time element is one of great importance in the phenomena under discussion, as it is but seldom that conditions of equilibrium are quickly reached when such solids are brought into solution.

It will be shown later that the probable origin of soluble carbonates, or "black alkali," in the soil is due to the action of another electrolyte, such as sodium chloride upon lime carbonate or lime-magnesium carbonate. The differences between the calcium carbonate and magnesium carbonate, which have been brought out in so marked a manner above, indicate that the formation of soluble carbonates would take place more readily and to a greater extent in those areas in which the lime carbonates in the soil contain also considerable quantities of magnesium carbonate. This view is very fully borne out by field experiences, especially in the studies of the Division of Soils upon the alkali areas of California and Utah.

SOLUBILITY OF GYPSUM IN AQUEOUS SOLUTIONS OF VARIOUS ELECTROLYTES.[1]

Gypsum is the dihydrate of calcium sulphate, $CaSO_4 2H_2O$. It is a common component of some soils in arid regions, and it may even be present in such quantities (as, for example, in certain areas of the Pecos Valley) as to form the major part of the soil. It is sparingly soluble in water, but more so than the usual soil components in humid regions. From the researches of Regnault and of Goldammer it appears that a liter of water at 0° C. will dissolve 1.9 grams of calcium sulphate, equivalent to 2.41 grams of gypsum; at 24° C. it will dissolve 2.09 grams of calcium sulphate, equivalent to 2.65 grams of

[1] The results of an investigation on this subject by Frank K. Cameron and Atherton Seidell will be described in detail in another publication of the Division of Soils.

gypsum. The solubility continues to increase with rise of temperature until at 37.5° C. a liter of water will contain 2.14 grams of calcium sulphate, equivalent to 2.71 grams of gypsum. From this point there is a decrease in solubility with increase in temperature, until at 82° to 83° C. the solubility is the same as at 0°, and at 99° a liter of water will contain 1.75 grams of calcium sulphate, equivalent to 2.22 grams of gypsum. There is some reason to suspect that this apparent solubility curve, with a maximum point at 37.5°, is, in fact, two curves, the one below 37.5° being in reality the solubility curve for gypsum, while the portion above 37.5° is the curve from the hemihydrate $CaSO_4\frac{1}{2}H_2O$. But this need not concern us here, for the purpose of this paper is to consider the solubility at temperatures below 37.5° C. Unless otherwise stated, the solubility determinations described in this paper were made at 25° C.

The presence of other electrolytes in the soil which do not yield a common ion would increase the solubility of the gypsum. Conversely, the presence of other calcium salts or other sulphates would be expected to decrease its solubility; but there are no published data involving the electrolytes commonly found in the soil of arid regions and available for alkali studies. Moreover, while the application of the mass law will give at least approximate ideas as to the conditions in solutions of very moderate concentration, it can not be expected to hold for more concentrated solutions of electrolytes; and it is just these more concentrated solutions with which we have to deal in alkali investigations.

It is of the utmost importance in dealing with the solution of substances of very moderate solubility to give due consideration to the time element. For example, it is necessary sometimes to evaporate to dryness solutions containing calcium salts and sulphates. On desiccation there is a separation of gypsum crystals, and on redilution to the original volume it is practically impossible to get the gypsum again in solution in a reasonable time. This common experience has often led to much trouble, as well as erroneous conclusions. That the original conditions can be always again realized has been amply demonstrated in this laboratory, although the time required for solution may be weeks, depending largely upon the physical condition, size of crystals of the gypsum, etc. In illustration, three 100 c. c. portions of a solution, containing a considerable amount of sodium chloride and saturated with respect to calcium sulphate, were evaporated to dryness on the water bath. The residues were then washed into 100 c. c. measuring flasks and filled to mark. They were then set aside, being vigorously shaken from time to time. In one case, in which the gypsum crystals in the desiccated residue were quite small, the entire mass went into solution in eight days. In the other cases sixteen and twenty-two days, respectively, were required for complete re-solution.

SOLUBILITY OF GYPSUM IN SOLUTIONS OF SODIUM CHLORIDE.

A liter of pure water at 25° C. will dissolve 2.1 grams of calcium sulphate or 2.7 grams of gypsum. A liter of solution containing 10 grams of sodium chloride and at the same temperature will dissolve 3.5 grams of calcium sulphate or 4.4 grams of gypsum. With 49 grams of sodium chloride, a liter of solution will dissolve 5.9 grams of calcium sulphate or 7.5 grams of gypsum. The solubility of gypsum increases with concentration in sodium chloride until in a solution containing from 135 to 140 grams per liter of sodium chloride there will dissolve 7.5 grams of calcium sulphate, equivalent to 9.3 grams of gypsum, that is, the solubility is nearly 3.5 times that in pure water. From this point the solubility decreases with increased concentration of sodium chloride, until with 306 grams of this salt a liter of the solution will only dissolve 5.7 grams of calcium sulphate or 7.2 grams of gypsum.

This existence of this maximum solubility point[1] was entirely unlooked for, and not to be foreseen by an application of the mass law principle to the reaction expressed thus:

$$CaSO_4 + NaCl \rightleftarrows CaCl_2 + Na_2SO_4.$$

It seems possible that the existence of this maximum solubility was only apparent and not real. The determinations were made on the basis of the mass of the salts present as compared with the volume of the solution. And in the more concentrated solutions the dissolved salts themselves might have so large a total molecular volume as to notably displace some of the solvent from a given volume. A redetermination of the solubility curve was then made on the basis of the mass of salt dissolved by a constant weight of water, when it was found that the maximum solubility had a real existence in a solution containing, for every 100 grams of water, about 15.3 grams of sodium chloride and 0.76 grams of calcium sulphate. The existence of this maximum solubility is one of great importance in making clear some phenomena observed in alkali studies. It probably gives a clew to the explanation of the formation of gypsum layers in the soil, which sometimes become very compact and are a serious menace to successful irrigation. It will be observed that the solution begins to separate gypsum before it contains half enough sodium chloride to saturate it with respect to the latter salt.

By the interaction of sodium chloride upon gypsum there is formed some calcium chloride and an equivalent amount of sodium sulphate. These salts are brought to the surface in the capillary rise of the soil waters, and on evaporation of the latter are deposited to some extent as such in the upper part of the soil or as a crust upon it. When

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[1] Tilden and Shenstone (Proc. Roy. Soc., **38**, 335, 1885) found a maximum solubility for gypsum in solution of sodium chloride. For several reasons, however, it was considered desirable to reinvestigate this pair of electrolytes.

water comes upon the surface of the soil the calcium chloride, because of its physical condition, that is, not crystallized as would be the other salts, and its great solubility, is very completely leached out by the first waters and carried down into the soil through the larger soil openings far ahead of the other salts, which dissolve more slowly. It thus accumulates and moves through the subsoil, and under excessive drought or other special conditions comes to the surface in areas, generally of quite limited extent. Owing to its great hygroscopicity, or power of attracting moisture from the air, it keeps the soil in which it occurs damp and moist, giving to it in consequence a darker color than the surrounding soils. In consequence, such areas are frequently known as black alkali spots, although they may be, and generally are, quite free from soluble carbonates.

SOLUBILITY OF GYPSUM IN SOLUTIONS OF MAGNESIUM CHLORIDE.

The phenomenon presented is very similar to that observed in sodium chloride solutions. A liter of the solution containing 8.5 grams of magnesium chloride will dissolve about 4.26 grams of calcium sulphate or 4.82 grams of gypsum. The amount of calcium sulphate dissolved will be twice that dissolved by pure water. With increasing concentration of magnesium chloride the solubility of gypsum increases, until with a concentration of about 102 grams of magnesium a liter of the solution will dissolve 8.6 grams of calcium sulphate or 9.7 grams of gypsum. The solution will then contain more than four times as much calcium sulphate as pure water would dissolve. From this point on, the solubility of gypsum decreases with increase of concentration with respect to magnesium chloride. A liter of solution containing 440 grams of magnesium chloride was found to dissolve less than 1.4 grams of calcium sulphate, corresponding to about 1.6 grams of gypsum. The solubility in such a solution, therefore, is markedly less than in pure water. The composition of the solution at the maximum point is approximately 11 grams magnesium chloride and 0.895 gram $CaSO_4$ per 100 grams of water.

It is a noteworthy fact that if the solubility of gypsum to sodium chloride and magnesium chloride be compared on the basis of the amount of chlorine in the solution, the maximum point comes at very nearly the same concentration for chlorine in the two cases. But the amount of gypsum dissolved at the maximum point is quite different for the two cases, so that it does not appear that there is any causal connection in the phenomena observed.

With the sodium chloride the action of magnesium on gypsum results in the formation of calcium chloride, and the same observations made in that connection above hold for this case also.

Recent investigations in the Division have shown that the soluble magnesium salts are about the most noxious in their conduct toward

plant growth of all the salts that occur in alkali soils, but in contact with gypsum their solutions become markedly less harmful.

That plants can not survive in a culture medium containing magnesium salts, unless a sufficient amount of calcium be also present, has long been known.[1] Dr. Loew[2] and Mr. May, of the Division of Vegetable Physiology and Pathology, in an extended investigation, the results of which have not yet been published, have shown the value of calcium as a corrective for the toxic effects of magnesium. More recent investigations, undertaken by the Division of Soils conjointly with the Division of Vegetable Physiology and Pathology, have shown that soluble magnesium salts are about the most noxious in their conduct toward plant growth of all the salts that occur in alkali soils; but in contact with gypsum their solutions become markedly less harmful. This is probably due in large part to the increase in the solubility of the gypsum and a corresponding increase of the active mass of the calcium in the solution. The plant may be able to use more, or at least withstand more, magnesium if it receives a more liberal amount of calcium in its food supply. It seems possible that the proteid compounds of calcium in the protoplasm are better adapted to the plant's economy than the corresponding magnesium proteid compounds; but the former can only be formed in sufficiently large proportions when the active mass of calcium in the nutritive solution is sufficiently large and the plant is not forced on account of a deficiency to supply its place with magnesium, the chemical analogue of calcium. This is essentially the view held by Loeb[3] and by Pauli[4] as a result of their investigations upon the influence of salts and salt mixtures upon animal tissues.

The importance of precise information on the mutual solubility effects of salt mixtures for these physiological studies is obvious, and in the intelligent investigation of plant life on alkali soils it is indispensable.

SOLUBILITY OF GYPSUM IN SOLUTIONS OF CALCIUM CHLORIDE.[5]

To solutions of calcium chloride, gypsum would give a common ion, namely, the calcium ion. Its solubility in such solutions would be

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[1] For references to work on this subject, see Drude Handbuch der Pflanzengeographie, p. 51 et seq., and more especially Schimpfer Pflanzengeographie, p. 105 et seq. Wolf (Landw. Versuchsst., 7, 202 (1865) quotes Mettenius as to the noxious effect of magnesium salts, and the results upon the contents of the epidermal cells of the bean and maize, but himself found that it could be corrected by the presence of salts of calcium, potassium, or ammonium, especially by the salts of the first-mentioned metal. Precisely similar results on the cells of animal tissues have been observed by Loeb in his investigations with salts and salts mixtures.

[2] See Bulletin No. 18, Div. of Veg. Phys. and Path., pp. 42 and 43 (1899).

[3] Pflüger's Archiv., 75, 303 (1899).

[4] Ueber physikalisch-chemische Methode und Probleme in der Medizin, p. 19, Wien (1900).

[5] Lunge [Jour. Soc. Chem. Ind., 4, 31 (1885)] obtained results with this pair of electrolytes, which accord quite well with those presented here.

expected to be less than in water alone. It was found that its solubility did decrease very rapidly as the concentration with respect to calcium chloride increased, until in a solution containing 7.5 grams calcium chloride per liter less than 1.25 grams of calcium sulphate or 1.4 grams of gypsum would dissolve in a liter of the solution. From this point on, the solubility steadily decreased, until a liter of a solution containing 368 grams of calcium chloride only dissolved 0.032 gram of calcium sulphate. One may say that while, in round numbers, a 1 per cent solution of calcium chloride will dissolve only half as much calcium sulphate as pure water, there will still be an appreciable amount of gypsum taken up by a 40 per cent solution.

SOLUBILITY OF GYPSUM IN SOLUTIONS OF SODIUM SULPHATE.

The solubility of gypsum in solutions of sodium sulphate would be expected to be less than in pure water, for the two salts furnish a common ion. It was found that the solubility did decrease, until a liter of solution containing 15.6 grams of sodium sulphate dissolved only 1.4 grams of calcium sulphate, or a little less than 1.6 grams of gypsum. From this point, with increasing concentration of sodium sulphate, the gypsum apparently increased in solubility, probably due to the formation of a double sulphate of calcium and sodium, until a liter of solution containing 223 grams of sodium sulphate dissolved nearly 2.3 grams of calcium sulphate or 2.6 grams of gypsum. A solution containing 115 grams per liter of sodium sulphate dissolved about the same amount of gypsum as did pure water. These facts are important in showing that gypsum is dissolved to a considerable extent, and transported in the soil even, by solutions containing sodium sulphate.

SOLUBILITY OF CALCIUM CARBONATE IN AQUEOUS SOLUTIONS OF VARIOUS ELECTROLYTES.

As has been pointed out in a former paragraph, calcium carbonate, in going into solution in natural waters, is more or less completely converted into the corresponding hydrogen carbonate. It was desirable, therefore, in determining the solubility of the calcium carbonate in the presence of other salts to bring the solutions into equilibrium in contact with an atmosphere containing a constant proportion of carbon dioxide. This condition was obtained with sufficient accuracy by passing a current of air through the solutions in contact with the solid calcium carbonate until they had come to a final state of equilibrium. It is very probable that the solubility values found are lower than those which actually obtain in soil solutions. But they are sufficiently near the truth to be of value in obtaining an insight into the processes taking place in the soil, and have the further value of being made under conditions which can be readily realized at any time, and thus become available for comparison with other determinations of a like nature which may be made subsequently.

SOLUBILITY OF CALCIUM CARBONATE IN SOLUTIONS OF SODIUM CHLORIDE.

It was found that after passing air through a series of solutions of sodium chloride in contact with solid calcium carbonate for twenty-seven days final equilibrium had undoubtedly been obtained. It was probable that such a long time was not necessary, and that, in fact, the equilibrium conditions had been reached in from eight to ten days. Curiously, the solutions appeared to contain no normal carbonate, but only hydrogen carbonates and chlorides. In water alone, that is, without any sodium chloride, it was found that a liter dissolved 0.1046 gram of calcium hydrogen carbonate, equivalent to 0.0646 gram of calcium normal carbonate. A liter of solution containing 9.7 grams of sodium chloride (approximately a 1 per cent solution) dissolved 0.177 gram of calcium hydrogen carbonate, equivalent to 0.1094 gram of the normal carbonate. The solubility increases until a liter of solution containing about 53 grams of sodium chloride will dissolve about 0.2255 gram of calcium hydrogen carbonate, equivalent to 0.1394 gram of the normal carbonate, or more than twice the amount dissolved by the water alone, and about 10.5 times that dissolved by pure water free from carbon dioxide. Beyond this point the solubility steadily decreases with the increase in concentration of sodium chloride, until a liter of solution containing 260 grams of this latter salt only dissolves 0.1227 gram of calcium hydrogen carbonate, equivalent to 0.0758 gram of normal carbonate.

It thus appears that the maximum solubility is reached in about a 5 per cent solution of sodium chloride. The precipitation of calcium carbonate from solutions as they become more concentrated than this is probably an important factor in the formation of calcium carbonate deposits in the soil and calcareous hardpan. As the formation of soluble carbonates in the soil is probably due in the main to the action of other electrolytes upon calcium (or calcium and magnesium) carbonates, it is interesting and important to observe that the process will take place to a maximum extent in solutions of this rather moderate concentration. This statement must be modified somewhat if there be much magnesium carbonate associated with the lime carbonate, and it will be referred to again.

SOLUBILITY OF CALCIUM CARBONATE IN SOLUTIONS OF SODIUM SULPHATE.

The solubility of calcium carbonate increases quite rapidly at first and then more gradually as the concentration with respect to sodium sulphate increases. A solution containing 5 grams per liter of sodium sulphate dissolved 0.173 grams of calcium hydrogen carbonate, equivalent to 0.107 grams of the normal carbonate. The solution, however, contained only a faint trace of normal carbonate, practically all the calcium being combined in the form of the hydrogen carbonate. In a solution containing 35 grams per liter of sodium sulphate the calcium dissolved was equivalent to 0.325 grams of the hydrogen carbonate or

0.201 grams per liter of the normal carbonate. As a matter of fact, about 8 per cent of the calcium was in the form of normal carbonate, the remainder of the base being combined as the hydrogen carbonate. With 160 grams of sodium sulphate per liter 0.459 grams per liter of the hydrogen carbonate, equivalent to 0.283 grams per liter of normal carbonate, was dissolved, about 18 per cent of the calcium being in the form of normal carbonate.

Three points of special interest were brought out in studying this pair of electrolytes. It is evident that calcium carbonate is decidedly more soluble in solutions of sodium sulphate than in solutions of sodium chloride of equivalent concentrations, in spite of the fact that in the first case a slightly soluble salt, calcium sulphate, is formed, and in the latter the very soluble salt calcium chloride is formed.

In the next place it was found that when calcium carbonate was in contact with solutions containing more than a half per cent of sodium sulphate there was formed some soluble normal carbonate as well as hydrogen carbonate, whereas in the case of sodium chloride solutions only hydrogen carbonate was formed.

Finally, it appeared that this case was unlike others, in which there was a pair of electrolytes which do not yield a common ion, in that there does not appear to be a maximum point on the solubility curve; that is to say, there seems to be steady increase in the solubility of the calcium carbonate with increased concentration of sodium sulphate.

These facts are of great interest in alkali investigations, for they indicate that the contact of sodium sulphate with calcium carbonate is of greater importance in the formation of black alkali than is the contact of sodium chloride with calcium carbonate, and that there must be, moreover, enough calcium sulphate or gypsum present to saturate the solution with respect to it in order to counteract the formation of the noxious soluble normal carbonates. In consequence, it is obviously unsafe to presume that in all cases where irrigating waters are found to carry sulphates in solution that their application to soils containing black alkali will prove beneficial. Quite the reverse may be true.

SOLUTIONS OF SODIUM CHLORIDE IN CONTACT WITH CALCIUM CARBONATE AND CALCIUM SULPHATE SIMULTANEOUSLY.

As in the other cases where the solutions were in contact with calcium carbonate, air was passed through the solutions until they had come to equilibrium. It was found that the presence of calcium carbonate decreased somewhat the solubility of the calcium sulphate, although the general nature of the solubility curve for calcium sulphate and sodium chloride was the same as when the calcium carbonate was not present. The effect of the presence of the calcium sulphate on the solubility of the calcium carbonate was very marked. There was no soluble normal carbonate formed, and the amount of

hydrogen carbonate was quite small. In the solution containing no sodium chloride a liter contained 1.999 grams of calcium sulphate and 0.051 grams of calcium hydrogen carbonate. About 2 per cent of the calcium dissolved was in the form of the hydrogen carbonate, the remainder being taken from the sulphate. In a liter of a 1 per cent solution of sodium chloride there was dissolved about 3.5 grams of calcium sulphate and 0.06 grams of calcium hydrogen carbonate. The maximum solubility was reached in about an 8 per cent solution of sodium chloride when a liter dissolved 6.3 grams of calcium sulphate and 0.06 grams of calcium hydrogen carbonate. About 0.8 per cent of the calcium dissolved came from the carbonate, the remainder coming from the calcium sulphate.

A liter of solution containing 280 grams of sodium chloride dissolved 4.7 grams of calcium sulphate and about 0.045 grams of calcium hydrogen carbonate, somewhat less than 0.8 per cent of the calcium coming from the calcium carbonate.

These results are in entire accord with field observations, which have shown that when gypsum was present in the soils, or was applied to it, no black alkali was to be apprehended, even when calcium carbonate was also present. It is possible that this view would require qualification if there were much magnesium carbonate associated with the calcium carbonate. The small amounts of bicarbonate found, which would probably be somewhat greater in the soil solutions, were a warning, however, that can not be safely neglected; for if they be concentrated at the surface by evaporation and capillary movement of the soil waters black alkali will result, unless enough solid gypsum is always present to force back the dissociation of calcium carbonate and precipitate it from the solution. The application of gypsum to lands containing black alkali is to be considered rather as a more or less temporary amelioration than a cure for the evil.

SOME APPLICATIONS OF SOLUBILITY DETERMINATIONS.

The solubility determinations recorded in the foregoing paragraphs will find their main application in the study of the processes involved in the formation and transportation of alkali in the soil. It is believed that much practical knowledge will be gained from them as to what is to be expected on giving soils of certain treatment. Much gratifying success has already been met in interpreting certain observed phenomena in the field in the light of these studies; but it is deemed advisable to postpone an exhaustive discussion of the subject until our studies have progressed somewhat further. There are still required studies of several pairs of electrolytes and an extension of the work to a few more complex systems, as well as a comparative study of field conditions, before this work can be profitably put in final shape for publication. It has already very much advanced our general knowledge and given a clearer insight into alkali phenomena, some evidences of which will appear in this report.

The concentrations of the solutions, to which attention has been more especially directed in the foregoing paragraphs, are far beyond those which occur in the soil in the presence of any ordinary cultivable plants during growth. But, also, for such solutions as plants will stand, these solubility determinations will be found helpful in understanding the phenomena presented. As an illustration, let the effect on gypsum of one-half per cent solutions of some of the common electrolytes be considered. The amount of calcium sulphate which will be taken up is given in the following:

One-half per cent solution of $MgCl_2$ will dissolve 3.45 grams $CaSO_4$ per liter.
One-half per cent solution of NaCl will dissolve 3.05 grams $CaSO_4$ per liter.
Pure water will dissolve 2.09 grams $CaSO_4$ per liter.
One-half per cent solution of Na_2SO_4 will dissolve 1.53 grams $CaSO_4$ per liter.
One-half per cent solution of $CaCl_2$ will dissolve 1.30 grams $CaSO_4$ per liter.

It will be seen that calcium sulphate is dissolved by all of these solutions to a considerable extent, even in those which yield with calcium sulphate a common ion. It is a necessary consequence that there will be in the solution some calcium, and that the chemical activity of the other electrolytes will be diminished either by a partial formation of a calcium salt and a sulphate, if it does not yield a common ion, or by a forcing back of its dissociation if it does yield a calcium ion or a sulphion. It has been clearly shown in the laboratory that the deterrent effect of two or more electrolytes on plant growth is not cumulative, certainly not in an additive sense; and more especially are plants able to withstand harmful quantities of other salts where calcium salts are present. It would seem, therefore, that the addition of gypsum to soils containing harmful quantities of other salts may be advisable, even though it means an increase in the total amount of soluble material in the soil. For this latter reason great caution should be exercised in its application, and it should rather be regarded as a possible temporary expedient pending a removal of the excess of soluble material by irrigation with drainage. Moreover, on account of its much greater solubility and the fact that it does not lead to the formation of carbonates, it is evident that gypsum is a more desirable medium for the application of calcium to soils not troubled with the excess of soluble material and in need of this element than is lime or lime carbonates. Again, gypsum is not so likely to contain excessive quantities of magnesium, which is sometimes added to a soil to its detriment with lime or lime carbonates. Obviously gypsum or land plaster can not take the place of lime or lime carbonate when it is applied for the purpose of neutralizing the acidity of a soil, and it is doubtful if it alone would be found so advisable where it is intended to cultivate those leguminous crops with which are associated the nitrifying organisms.

The solubility of calcium carbonate is very much less than the solubility of gypsum. A half per cent solution of sodium chloride will

only dissolve about 0.15 gram per liter of calcium hydrogen carbonate and a half per cent of sodium sulphate will only dissolve about 0.17 gram per liter of calcium hydrogen carbonate. The quantity of calcium taken up from calcium carbonate by half per cent solutions of the more soluble salts is thus seen to be very much less than that which would be obtained from gypsum under similar conditions. It follows therefore that the calcium will be in a much more readily available form when applied as gypsum or land plaster, and it indicates the explanation of the fact that plants will stand much larger quantities of soluble salts in the presence of gypsum than they will in the presence of calcium carbonate. The apparent presence of calcium hydrogen carbonate in the solution really means the presence of sodium hydrogen carbonate, and this substance, while comparatively harmless in itself, means the possibility that sometimes it may partially invert with the formation of the dreaded black alkali.

With an excess of gypsum the formation of black alkali will be practically nil, and it would seem possible that the best practice for many soils (especially acid soils in humid regions) would be to lime with a mixture of gypsum or land plaster and the oxide or carbonate of lime. A number of interesting investigations on the practice of liming suggest themselves in this connection.

A CLASSIFICATION OF ALKALI SOILS.[1]

The studies of the Division have now reached the point where a classification of "alkali" seems desirable which will be more specific than the long-time conventional and sometimes misleading one of "black alkali" and "white alkali." On chemical grounds this can be done very conveniently by considering the predominating reaction or reactions in the electrolytes of the particular localities and which may be taken to characterize those localities. In the majority of cases this is easily done, as the predominating reaction is that of a very soluble electrolyte, such as sodium chloride, upon a slightly soluble electrolyte, as gypsum or calcium carbonate.

PECOS TYPE.

The action of sodium chloride upon gypsum in the presence of water is to increase its apparent solubility with the formation of sodium sulphate and calcium chloride. Under the conditions that exist in the soil the calcium chloride is apt to become segregated, as has been pointed out above, and so the most apparent result of the reaction is to add sodium sulphate to the sodium chloride in the soil. In the valley of the Pecos River in New Mexico just such conditions prevail. Other soluble electrolytes do occur in the soil, but they appear to be comparatively unimportant in quantity and effect. Since this was the first area of the type to be given extended investi-

[1] See Bulletin No. 17, Division of Soils.

gation by the Division of Soils, it is proposed tentatively to give the name to the type.

FRESNO TYPE.

The action of aqueous solutions of sodium chloride upon calcium carbonate under soil conditions yields calcium chloride and sodium hydrogen carbonate. This latter inverts, in part at least, to the normal carbonate, forming the dreaded "black alkali." Such conditions are the prevailing ones in the alkali areas about Fresno, in the San Joaquin Valley in California, and the type has been named in accordance with this fact, as it is the first area of the type to be studied by the Division.

SALT LAKE TYPE.

In the Salt Lake Valley the principal soluble electrolyte in the soil is sodium chloride, which is brought into contact with both gypsum and calcium carbonate simultaneously, these latter salts being common components of the soils in this area. There will be formed calcium chloride, sodium sulphate, and sodium carbonate or hydrogen carbonate. The formation of sodium hydrogen carbonate, though comparatively small in amount when sodium chloride acts on calcium carbonate alone, will be very much less in the presence of gypsum, and is generally a negligible quantity economically considered. In a similar manner, though to a less extent, the presence of calcium carbonate retards the formation of sodium sulphate by the action of sodium chloride upon gypsum. The characteristics of this type are the presence of very small, generally negligible, quantities of black alkali, the presence of soluble sulphates, and the rather common occurrence of "calcium chloride spots." The occasional occurrence of nitrates and phosphates is more common in this type than in others, probably because the organisms which give rise to them find suitable food and lime carbonates to neutralize the acid products they form at the same time.

BILLINGS TYPE.

In the Yellowstone Valley the alkali apparently consists almost entirely of soluble sulphates, probably derived from the oxidation of iron sulphides common in the parent rock, to sulphates. By hydrolysis free sulphuric acid would be formed, and by its action on the soil components, in turn, soluble sulphates. There are occasionally small amounts of calcium carbonate in the soils of this area, and in consequence very small amounts of soluble carbonates. These last may be safely neglected, however, as a characteristic of the type of alkali.

MODIFICATIONS OF TYPES.

Other types may be found worth defining as the study of alkali conditions progresses and other features than strictly chemical ones may be necessarily incorporated. For the present, the classification

above seems sufficient and satisfactory. There are areas, however, which present features not strictly like the types given, but which may still be regarded as modifications of them rather than as illustrating new types. For instance, in the Sevier Valley, Utah, the predominance of soluble hydrogen carbonates in the soil is the most striking feature. This area is to be regarded as a modification of the Fresno area, the primary reaction of importance being the action of sodium chloride upon calcium carbonate, but the total amount of alkali being so small as to make the distribution of the bases between the carbonates and hydrogen carbonates greatly in favor of the latter salts.

About Phoenix, Ariz., the alkali originally is primarily of the Fresno type; but the irrigation water, which is being added to a large part of the area, carries considerable amounts of soluble sulphates, with the result that the conditions gradually approach those characteristic of the Salt Lake type.

OCCASIONAL OCCURRENCES OF ALKALI IN HUMID REGIONS.

Occasionally conditions very similar to those which obtain in arid regions may exist temporarily in humid regions. Several such instances have come to the notice of the Division. In May, 1900, Professor Whitney observed a dark crust or stain on the borders of a roadway through a field belonging to the Maryland Agricultural Experiment Station at College Park, Md. Samples of this crust were obtained for the Division by Prof. W. T. L. Taliaferro. In the crust as collected there was nearly 2 per cent soluble material, an analysis of which yielded the following results:

NO_3	Cl	SO_4	Ca	Mg	Na	K
68.93	4.82	1.31	15.64	3.34	3.34	2.41

Combined in the conventional manner:

$CaSO_4$	$CaCl_2$	$Ca(NO_3)_2$	$Mg(SO_3)$	$NaNO_3$	KNO_3
1.86	7.55	51.20	20.68	12.47	6.24

The amount of soluble material was sufficient to classify the soil as an alkali soil, and it was certainly sufficient to prohibit the growth of any ordinary crops. More than 80 per cent of the material was in the form of calcium and magnesium salts, of which the magnesium salts formed a fourth. The proportions of nitrates was astonishingly large. Diligent inquiry has failed to bring out any information as to the origin of this material. Its occurrence as a soil crust is most interesting and instructive. It was found toward the end of a period of protracted drought and on a soil surface which was smooth and compact and from which evaporation must naturally have been excessive. It seems probable that the soluble material may well have been brought from a very large volume of soil through capillary movements of the soil solutions and concentrated on this much-restricted surface on account of this excessive evaporation from it. No trace of the crust

could be found on the surface of the field adjoining the roadway, nor did samples of the surface soil from the field show unusual amounts of soluble material.

A similar formation of a crust of soluble soil components on a pathway in Bradford County, Fla., was observed by Professor Whitney some years since. Again, the conditions of drought and a surface from which unusual evaporation could readily take place were present. It is desirable evidently that the repetition of such occurrences should be observed and studied. Moreover, it shows the importance already recognized in general of keeping down the evaporation of moisture from the surface of the soil, by mulching or otherwise, even in the humid East, not only to conserve the moisture itself, but to prevent the harmful accumulation of otherwise desirable soil components.

ESTIMATION OF CARBONATES, BICARBONATES, AND CHLORIDES.

Experience has shown the desirability of quick and approximately accurate methods for determining the nature and relative composition of the easily soluble constituents in the soils of arid regions. The relation of the soluble carbonates to bicarbonates or hydrogen carbonates is of special importance because the ratio between these components is much changed in the transit of the soil sample from the field to the laboratory. The method for the estimation of the carbonates, bicarbonates, and chlorides has been so far perfected now as to leave but little to be desired in its use either in the laboratory or the field. In brief, the methods consist in titrating a solution prepared by shaking the soil in water, with a twentieth normal solution of hydrogen potassium sulphate, using phenolphthalein as the indicator, until loss of color. The number of cubic centimeters is then read off and multiplied by 0.002978, giving the grams of the radical CO_3 present. Methyl orange is then added as an indicator, and, without refilling the burette, the titration continued until change of color. Another reading on the burette is taken, and this reading less twice the reading taken for the carbonates is multiplied by the factor 0.003028 to give the number of grams of the radical HCO_3 present.

A drop or two of a solution of potassium chromate solution is now added and tenth normal silver nitrate solution added until change of color. The amount of chlorine present is thus easily determined by multiplying the reading on the burette by the factor 0.003518. A table for converting these determinations from actual burette readings to the mass of the corresponding sodium salts present is carried by the field party, and has been found very convenient in practice.

It has been shown that more accurate results can be obtained by using small amounts of indicator, but this led to great difficulty in the use of methyl orange, an indicator presenting considerable difficulties, even under the best conditions, on account of the masking of the delicate color of the substance in acid solutions by the unchanged indicator

at the end of the titration. This difficulty is the greater because it has been shown that the titration gives the most accurate results when stopped at the first change of color when using this indicator. In solutions carrying much suspended clay or dark in color the use of methyl orange is absolutely prohibited. It has been found that Congo red works quite well in such solutions, giving a strong, well-marked color, and the titration should be continued until there is no further change of color. Congo red is, however, not so delicate an indicator as methyl orange, and when accurate work is desired the latter should be used if the conditions permit. Much trouble has been experienced in the field from the fact that considerable amounts of solid calcium (and magnesium) carbonates were often suspended in the soil solutions in the form of clay and would not subside within a reasonable length of time. A titration for the determination of bicarbonates is usually impracticable under such circumstances, for the suspended soluble carbonates react with the hydrogen potassium sulphate so quickly as to make it impossible to determine the end point of the reaction between the acid and the dissolved hydrogen carbonates. It is believed this trouble has been met by Mr. Briggs, who has devised an instrument for the rapid filtration of solutions containing suspended clay and other material without changing materially the ratio of the dissolved normal carbonates to the hydrogen carbonates.

Since the ratio of the normal carbonates to the hydrogen carbonates has been found of such importance in the investigation of soils in the arid regions, it is obviously improper to use for the preparation of the soil solutions water which carries much dissolved carbon dioxide. It has been necessary, therefore, to boil from time to time the water used to expel the dissolved carbon dioxide, and the wash bottles are fitted with blow bulbs for the expulsion of the water, thus avoiding the addition of carbon dioxide by blowing into the bottles from the mouth.

CHEMICAL PHENOMENA PRESENTED BY SOME ALKALI VEGETATION.

Observations on the vegetation of an area, whether indigenous or artificially introduced, have proven most helpful in many ways in the field study of alkali conditions. Problems have been met, however, in this connection which could not be made clear without more detailed study than was possible in the field, and yet were of sufficient importance to merit an exhaustive examination. A description of some laboratory work in this direction is here given.[1]

FORMATION OF BLACK ALKALI BY PLANTS.

It has been attempted for some time to cultivate certain plants, notably the so-called salt bushes, on soils adapted to them, in the hope of making these otherwise useless soils available for the production

[1] A detailed description of this work will shortly be published in a bulletin of the Division of Vegetable Physiology and Pathology.

of forage crops. With some of the plants there is an element of danger, which has been pointed out by Hilgard and by Goss and generally believed in the arid regions, in that they form black alkali from the less noxious white alkali which alone was originally present in the soil before their cultivation. Certain it is that soluble carbonates often can be found in more than traces in the soil about or under these plants, whereas no traces of it can be observed in the soil a few yards away. An examination from this point of view of some of the typical alkali vegetation seemed desirable, and samples were sent to the laboratory.

The creosote bush (*Covillea tridenta*), while a desert plant, is said to shun soils where there is much water soluble material, and its presence may be taken as a sure indication of land free from injurious amounts of alkali. An ash analysis of an air-dried specimen showed that the leaves contained about 10 per cent mineral matter, while the stems contained about 5.6 per cent, or somewhat more than one-half as much. From the ash analysis it would appear that the air-dried leaves contained 0.55 per cent of their whole mass as sodium chloride, and sodium combined as carbonate to the extent of 0.86 per cent. The stems apparently contained 0.19 per cent sodium chloride and about 1 per cent sodium carbonate.

Water extracts of the ground leaves and stems failed to show either chlorides or carbonates, but were slightly acid; so that it would seem that while there was undoubtedly chlorine in the plants it was not present as inorganic chlorides, but more probably in organic combination. The sodium was present in much larger quantities than sufficient to combine with the mineral acids present, and was probably in organic combination; so that the ultimate decay of the plant tissue might very well be expected to yield considerable amounts of sodium carbonate, as was the case when burned to ash in the laboratory.

Greasewood (*Sarcobatus vermiculatus*) is a typical alkali plant, its presence being a pretty sure indication of much water soluble material in the soil. Experience has shown that it is almost invariably accompanied by soluble carbonates in the soil. The air-dried leaves of the sample analyzed yielded 25 per cent ash on combustion and the stems scarcely 5 per cent, or one-fifth as much. From an examination of the ash it was calculated that there was present in the leaves 5.3 per cent sodium chloride, 2.1 per cent sodium sulphate, and 13.4 per cent sodium carbonate. For the stems there was found 0.7 per cent sodium chloride, 1.2 per cent sodium sulphate, and 1.5 per cent sodium carbonate. A very thorough extraction of the leaves was made with water, and it was found that about 5.7 per cent sodium chloride was thus removed. The extract showed no trace of the presence of carbonates, but was slightly acid. The leaves were burned with fuming nitric acid and silver nitrate in a sealed tube, when an examination of the products of combustion showed that the material contained chlorine equivalent to 5.4 per cent. It thus appeared that

all the chlorine in the leaves was present as sodium chloride and none was in organic combination. It is probably true, although it was not proved quantitatively, that all the sulphur was present as sulphates, which could be readily leached out with water.

The sodium present in the leaves was found to be three times that required to balance the hydrochloric and sulphuric acids, and much of it was therefore present in the form of organic compounds which would yield the carbonate on decay. In this case the amount thus combined was much larger than usual; so that while it appears probable that all plants on decay will yield some soluble carbonates to the soil, this plant would be preeminent in this connection. In the arid regions where the plant is found these relatively large proportions of soluble carbonates can not be carried off by drainage through the soils. They accumulate under or about the plants, often to the serious and permanent detriment of the soil. This feature must therefore be taken into consideration in any intelligent scheme of cultivation looking to its use. It is in just those plants which are best able to stand large quantities of soluble salts in the soil and absorb these salts from the soil in greatest quantity that the most serious danger lies. The problem is a very important one, both for plant physiology and economic husbandry, and merits serious study.

RESISTANCE TO BLACK ALKALI BY CERTAIN PLANTS.

The presence of soluble carbonates or black alkali in the soils is notoriously fatal to most varieties of plant growth. A few varieties, however, have been observed to have the capacity to maintain themselves even in soils containing an unusually large percentage of soluble corbonates. These plants have been found to exude a very acrid, gummy substance or to secrete very acid juices in their stems and leaves, and it is due to this fact, probably, that they are able to maintain an existence under conditions that would at first sight appear absolutely prohibitory. The droppings or washings from the leaves and stems bring the acids which they secrete in contact with, and decompose the soluble carbonates about, their root crowns, and thus protect the plant from the corrosive action of sodium (or potassium) hydrate resulting from the hydrolysis of the corresponding carbonate. Nevertheless, the total amount of soluble material in the soil which these plants may stand is in itself very startling.

A sample of a grass (*Distichlis spicata*) was sent to the laboratory from the San Joaquin Valley, California. It was found growing in a soil which contained 3.8 per cent salts readily soluble in water. Of this soluble material the acid radical CO_3 formed 22.6 per cent and the radical HCO_3 formed 27.7 per cent. Calculated as the sodium salts, 40 per cent of the soluble material was normal carbonates and 38 per cent hydrogen carbonate, and together they compose nearly 3 per cent of the soil itself. The air-dried sample of grass found growing on this soil yielded over 4.5 per cent mineral matter when

extracted with water. Combining the mineral acids found with the other bases as far as possible, there was 35 per cent out of the 41 per cent of sodium in the mineral extract left unbalanced, and which must have been combined with the organic acid in the acrid exudation on the surface of this grass. In spite of the fact that 1.6 per cent of the plant was sodium combined with the organic acid, there was enough free acid on 1 gram of the air-dried material to neutralize 23 cubic centimeters of a twentieth normal (N/20) solution of potassium hydrate.

The analytical data obtained indicated the presence of considerable amounts of chlorides of calcium and magnesium on the surface of the grass. This was not apparent in the air-dried sample; but it is possible, and in fact probable, that much of the organic acid supposed in the foregoing paragraph to be combined with sodium was in reality combined with alkaline earth bases and the sodium was combined mainly as chlorides. It is noteworthy in this connection that in the field the grass is frequently found at some seasons to be gummy and covered with moisture even in the hottest and driest weather; and it is possible that hydroscopic chlorides may exist on their surface and, by attracting moisture from the air, keep them moist and enable the acid exudation to act upon the carbonates in the surface of the soil with which it comes in contact.

Other samples of this grass collected at a different season differed only in not being quite so acid and in containing a slightly larger amount of mineral matter easily extracted by water. In all other respects the samples were very similar. The small amount of material at disposal and the analytical difficulties encountered precluded an identification or thorough study of the acid exudation. It is intended to give it further attention in a future investigation.

The analyses of the water extracts of the sample of this grass show that about 0.6 per cent of the plant is potassium, which is easily leached out. The relatively large amount of this valuable asset in fertility which the plant removes from the soil is worthy of consideration in any economic use of the plant which may ever be contemplated. Evidence was obtained to show that the plant also extracts unusually large amounts of phosphates from the soil, although these substances are not readily extracted from the plant by water.

Samples of *Suaeda intermedia* and *Atriplex bracteosa* which were found on soils containing much soluble carbonates presented phenomena very similar to those recorded above for *Distichlis spicata*. In both these plants the accumulation of acrid material was found to be much greater in the leaves than in the stems, though in no case was it as great as in the *Distichlis spicata* described above. There were no indications, either in the analyses or in the appearance of the samples, to indicate the presence of hydroscopic salts on the surfaces. While both these plants evidently draw large quantities of potassium from the soil, the amounts do not appear so abnormally large as in the case of *Distichlis spicata*.

RESULTS OF TOBACCO EXPERIMENTS CONDUCTED IN VARIOUS PARTS OF THE UNITED STATES.

By MARCUS L. FLOYD.

INTRODUCTION.

The cigar-leaf tobacco trade has changes and fads, just as is the case with many other branches of business, though possibly the changes do not take place so rapidly as in many other lines. From 1840 to 1860 the Florida spotted leaf, of a rich mahogany color, was the style of wrapper leaf desired; then the requirements changed and a darker leaf was in favor, and for several years Pennsylvania and Connecticut furnished the most desirable leaf; the Pennsylvania leaf, being darker, was preferred. Soon, however, the requirements again changed, and for wrapper purposes a light-brown colored leaf was wanted; since which time, until very recent years, the Connecticut Valley has succeeded in producing the most acceptable domestic wrapper leaf. In 1860 the Sumatra leaf was first brought to our market. It did not meet with ready favor, for, while it was acknowledged by all to be a beautiful leaf, it was claimed that the taste was exceedingly bitter and the aroma quite unpleasant. For several years, therefore, the importer had hard work to win the trade over to the Sumatra leaf, preference being given to the Connecticut leaf. In time, however, its fine appearance, together with the wonderful wrapping capacity of the leaf, established it as the ideal cigar-wrapper leaf, and for more than twenty years this leaf has been the standard by which all other wrapper leaf has been compared and valued. While in the general order of things it would seem to be about time for the style to change, there is at present no evidence on the part of the trade that any change is likely to occur in the near future. It really seems exceedingly strange that this leaf should have been used so extensively for such a length of time and at such a cost to the cigar manufacturer, and that our farmers should never have tried to duplicate the leaf in this country, but have continued to grow the old lines of leaf, regardless of the change of requirements of the cigar-leaf trade. The lesson has been clearly taught that our own trade will not conform to or keep its requirements suited to our production. The tobacco growers must keep informed as to the changes in the

requirements of the trade, and must, by the introduction of new seed and new varieties and by such changes in methods of cultivation, harvesting, and curing as may be necessary to produce what the trade wants, endeavor to meet the trade demands.

The requirements of the trade, so far as regards fillers and binders, have never materially changed. Richness of flavor and aroma, with fine burning quality, are the essentials, and the island of Cuba has furnished the standard ever since the introduction of cigars into this country. The islands of Sumatra and Cuba have for years furnished the leaf for our high-grade cigars and our domestic leaf has been used largely for medium and low-priced goods. That this state of affairs can be in a great measure changed has been proven by experiments that have been conducted for the last ten years in the State of Florida by private capital and enterprise, and by experiments made in the Connecticut Valley by the Department of Agriculture, cooperating with the Connecticut experiment station during the year 1900.

The growing of cigar leaf in Florida is not a new industry for that State, but an old industry revived with new varieties of seed and new methods of cultivation, harvesting, and curing. During the fifties and sixties Florida furnished the most acceptable cigar-wrapper leaf produced, but on the advent of the Sumatra leaf the old Florida spotted leaf was no longer wanted and the production fell off until it was of no importance to the trade. During the eighties a few of the old tobacco growers of Gadsden County, Fla., and Decatur County, Ga. (these counties join, have the same soil formation, and were the principal tobacco-producing counties in the fifties and sixties, the entire product being known as Florida tobacco), procured fresh seed from the island of Cuba and planted small experimental plots. The product was sent to one of the largest cigar manufacturers of the city of New York, where the leaf was given a thorough test. The quality was found to be excellent, possessing the exact appearance and much of the rich flavor and aroma peculiar to the best Cuban leaf. So impressed were the New York people with the possibility of producing in Florida a tobacco of superior quality to anything that had ever been produced in this country that they sent agents to Florida to make a careful study of the soil and climatic conditions of the various sections of the State. These investigations resulted in their locating in Gadsden County, where they bought several of the best tobacco plantations and equipped them for the purpose of growing the leaf. This company was soon followed by other large leaf-tobacco packers of New York and Chicago, who began the culture of tobacco in Florida on a large scale.

With their first crop they began the work of experimenting, using different types of soil, various kinds of fertilizers, and while most of their crop was planted from the best Cuban seed, they also planted small plots with various other cigar-type seed. For filler purposes,

where flavor and rich aroma are the essential qualities, the Cuban seed proved best, but it failed to make a very high grade of wrapper leaf. Finally, in 1892, this concern secured a few seeds direct from the island of Sumatra and further experiments were made. It was found that on the ordinary ridge lands this type was a failure, but on the rich sandy hummocks a leaf was produced of excellent quality and in appearance quite equal to the imported Sumatra, although the percentage of fine leaf was exceedingly small. It was found that the old method of harvesting, that is, cutting the stalk as the plant matured, would not give good results. It was found necessary to have the leaves plucked from the stalk as they matured, that is, when the first three or four leaves near the bottom of the stalk reached the proper stage of ripeness they were plucked off, placed in baskets, and transported to the curing shed, where they were strung on strings by means of a large needle, from 35 to 40 leaves, according to the size of the leaf, being allowed to each string. In placing the leaves on the string it is necessary to so place them that their faces come together; otherwise in the process of curing one leaf would fold around the other. This method of harvesting is continued, the leaves being primed or plucked off as they ripen, until the entire stalk is stripped.

It was observed that when large trees were left standing in the newly cleared hammock lands that the plants growing near enough to be shaded by these trees had a thinner and brighter-colored leaf, and it may be said that this observation gave birth to the artificial shading which has recently attracted so much attention. Up to the time of the introduction of the shading process it was believed that a high grade of Sumatra leaf could be produced only on low hammock lands, for, while some fine crops had been produced on uplands, they were decidedly the exception and not the rule. However, in 1896, as an experiment, a New York company operating in Gadsden County, Fla., built a shed over 1 acre of old land.

The shed or arbor was 9 feet high and was covered with laths giving only half cover, that is, the laths were 2 inches wide and placed 2 inches apart, so that the plant received half sunshine and half shade. This acre was made very rich, the fertilizers used being cotton seed, cotton-seed meal, and cotton-seed hull ashes, and Sumatra tobacco was planted. The results were most gratifying, as a finer crop was harvested than had ever before been grown on the most desirable hammock land. The experiment was enlarged the following year with equally good results, and now there are at least 700 acres under shade in Gadsden County, Fla., and Decatur County, Ga. The method of shading has been changed from time to time, however, and now preference is given to the cloth shade, the same frame used for the laths being used to support the cloth cover. This cover is made of cheese cloth, which is now made 144 inches in width, and is very easily placed

on the frame. The frame is so constructed that the covering completely incloses the entire field, the door or gate to the field being also covered with this cloth. This cover, for several reasons, is far better than the slat covering: (1) It insures the crop against the ravages of worms and of hailstones; (2) it maintains a more even temperature, which is found to be from 5 to 10 degrees higher than the temperature outside, and consequently the growth of the plants is not checked by cool nights, as is the case with the crop grown without cover; (3) it is found that the soil retains moisture much longer. The atmosphere being humid and decidedly tropical, gives the plants a rapid and continuous growth from the time they are set until they are fully matured. While this covering protects the soil from rapid drying during a drought or during the prevalence of heavy winds, there have been droughts of such long duration as to cause the plants to show signs

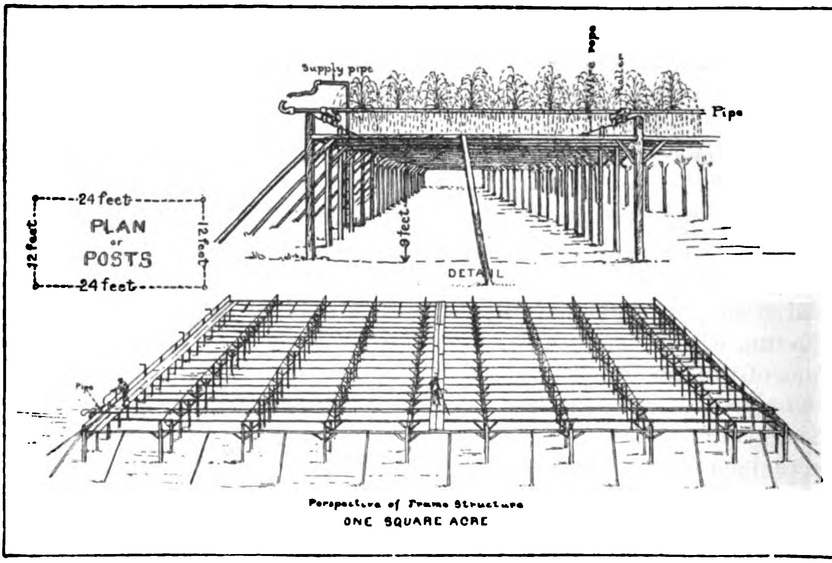

FIG. 46.—Plan of shade, showing method of irrigation as used in Florida.

of failing for want of moisture. Therefore many of the most aggressive farmers have put in irrigation plants, and along this line many experiments looking to the best method have been made. Subsurface and overhead irrigation have been tried. All who are at all familiar with irrigation understand the subsurface and surface method, while the overhead method used in these shaded tobacco fields is perhaps entirely new. It is illustrated in fig. 46. The details of this overhead method are as follows:

A 6-inch pipe leading from a reservoir or pump is run through the center of the field. Forty feet from the edge of the field a 3-inch standpipe is inserted into the main pipe. This pipe is 11 feet long, extending 2 feet above the frame of the shade. These pipes are put in every 80 feet across the entire field, each extending 2 feet above

the shade. Above the shade, extending across the entire field, a 3-inch pipe is laid (this pipe gives out a spray every 10 feet), being supported by trolley wires, the pipe resting on blocks that have a small grooved wheel at each end resting on the trolley wire. The pipe can thus easily be drawn along the wires across the entire field. In order to supply water to this pipe a 3-inch hose is attached to the standpipe and connected with the pipe running across the field, as described above. After the connection is made, water is turned on and the pipe moved along the wire as fast as the ground becomes sufficiently damp. The hose connecting these pipes should be 40 feet long. This would cover 80 feet, 40 feet on each side of the standpipe. When the ground has been sufficiently watered the hose is detached from standpipe No. 1 and attached to standpipe No. 2, and so on until the entire field has been watered. This work can be done very rapidly, and in a few hours many acres can be watered, the water by this method being applied just as a natural shower.

In order to manipulate the watering apparatus a plank walk is constructed across the field along by the standpipes. The moving of the long pipe that runs across the full length or width of the field is done by ropes attached to the pipe, which are drawn by hand, moving the pipe along the trolley wires from time to time as needed.

This method of irrigating may appear to be quite expensive, but as a matter of fact it is not so expensive as either the subsurface or surface method, and the structure does not block or hinder cultivation as does the surface method, as the entire plant is above the framework of the shade. Another point in its favor is that the water is more evenly distributed over the field and falls on the plants just as would a natural shower.

Tobacco is not a wet-weather plant, but a certain amount of moisture is at all times necessary to insure a continuous growth. This work is receiving great attention in Florida, and this year (1901) several hundred acres will be irrigated.

In preparing the soil the planter should endeavor to make the land sufficiently strong to develop the entire plant, so that in topping, if this is done at all, only the seed buds are taken out and all the leaves are allowed to develop. When the plants are topped low the leaves remaining on the stalk take on an abnormal growth, thicken, and lose the elasticity which they would otherwise have, thus ruining their value as a high-grade wrapper leaf. The rows should be about 3 feet 10 inches apart, this distance giving room enough for working the crop without damaging the leaves. In the drill 12 inches is quite sufficient distance to give the plants. With this close planting the leaves will be from 14 to 20 inches in length, these being the most desirable sizes for wrapper purposes. Tobacco grown in this way can only be harvested by the single-leaf method, that is, when the first three or four bottom leaves have reached the proper stage of

ripeness they should be harvested, and whenever it is found that other leaves have ripened they should be plucked off. In this way it is possible, with proper knowledge and care, to harvest a uniform crop of tobacco. When tobacco is harvested in the old way, namely, by cutting the stalk, the bottom leaves must be far overripe, the leaves in the middle of the stalk perhaps about right, while the top leaves are absolutely green.

The fact that a good crop has been grown and harvested is no assurance that the crop will be desirable when ready for market. The process of curing is yet to be gone through in the curing shed. This work is of the most vital importance and has for years claimed the closest attention of the best growers, for in the process of curing a good crop is often ruined and made almost valueless.

To properly cure a crop it is absolutely essential to have your barn so constructed that you will be able to control the interior regardless of what the weather conditions are. The illustration on page 461 shows the construction of the most modern barn. It will be seen that this barn can be ventilated from bottom to top when desired and can be absolutely tightly closed when it becomes needful to do so.

When tobacco is harvested by cutting the stalk it should ordinarily cure in from thirty to forty days. If harvested by the single-leaf process it should cure in from fifteen to twenty days. Every effort should be made to have the tobacco cure within the time above mentioned, but not sooner, as rapid curing for cigar leaf is also objectionable.

After filling a barn with green tobacco the barn should be tightly closed for two or three days, during which time the tobacco wilts down and becomes quite yellow. From that stage on the manipulation of the barn must be governed by the weather conditions. A continuous curing is desired, but not a too rapid curing. If the weather is exceedingly damp, and continues so for any great length of time, the barn should be tightly closed and small charcoal stoves, such stoves as are used by tinners, should be hung along the lower tiers of the barn and fires kept burning until the barn is thoroughly dried out. This work, if carefully and thoroughly done, will prevent mold. Mold is a serious trouble, though one is often told by the growers that it is of little consequence, as it can easily be brushed off. This is a great mistake; mold is rot in its early stage, and will clearly develop in the process of fermentation no matter by what process the fermentation is done. Damage received in the curing shed can never be overcome by the packer. By careful management the damage may be checked and not allowed to spread, but the damaged or molded leaf is beyond recovery, and therefore every planter, when preparing his tobacco for market, should be careful to throw out every leaf that is in the slightest degree so damaged. If the barn is properly constructed and kept in good condition, it is quite easy to prevent mold.

Before putting tobacco in a barn the barn should be thoroughly cleaned and well ventilated, all foul or musty air should be gotten out, all vegetation should be cut and raked away from the barn for several feet around the entire building, and water should never be allowed to stand in puddles in or near the barn. It is the practice of some of the most successful growers to cover the ground or floor of their barns with clean sand; the ground around the barn is also well raked off and covered with sand, thus insuring a good, wholesome atmosphere.

Rapid curing, as before stated, is objectionable and often results in great damage to the leaf, the damage being known to the trade as house burn, hickory or calico leaf, that is, the leaf becomes mottled, very uneven in color, and lifeless. This occurs when the weather is very dry and excessively hot during the curing season. The properly constructed barn will, when wisely manipulated, go far toward preventing this trouble. Some of the most successful planters in Florida have made further provision against this trouble by having water pipes run along the comb or saddle of the roof of the barn with sprays every 10 feet (see fig. 47). This has been done only by those who

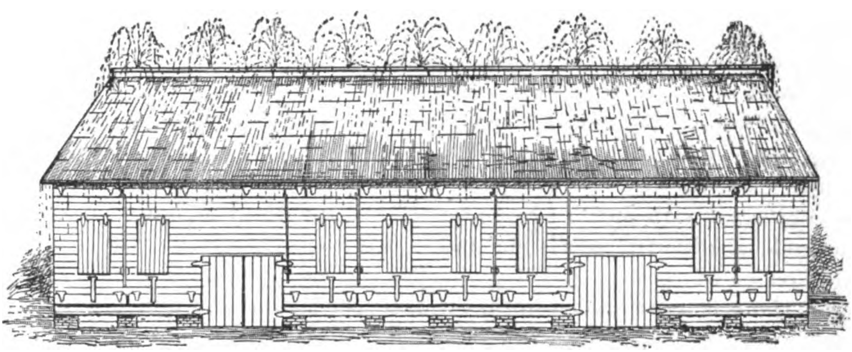

FIG. 47.—Plan of a tobacco barn, showing method of reducing temperature.

have irrigating plants. They run pipes from their field to the near-by barns. When the weather is too hot and dry and the tobacco shows that curing is going on too rapidly, water is turned on and the barn receives a regular shower, just as though it was raining, the result being that within an hour the temperature in the middle and top of the barn is reduced from 15 to 20 degrees, and, of course, the rapid curing is checked.

The trouble with the average tobacco grower is that when he produces in the field and harvests what is considered a fine crop of tobacco he feels that his work is done. This is far from being the case, however. The barn curing is of the greatest importance, and the sooner this fact is realized by the farmer the sooner he will succeed in placing on the market tobacco that will be acceptable to the trade.

The next step in preparing tobacco for the cigar manufacturer is the fermenting, classifying, grading, and packing in commercial

packages. This work is also of great importance and requires more skill and knowledge than perhaps any other part of the work. The purpose of fermenting tobacco is to eliminate certain objectionable properties of the leaf and to develop and bring out rich flavor and aroma.

This work also prepares the tobacco for keeping. Tobacco that has been properly fermented and packed in just the right condition will not damage, but will keep almost indefinitely when stored in a suitable place, and, while it is not advisable to keep the wrapper grades for more than from eight to twelve months after fermenting, as after that length of time they are inclined to lose their luster and elasticity, the filler grades will mellow with age and become richer in flavor and aroma. For two or three years at least there will be improvement in the quality of the filler grades; after that length of time it is the opinion of the best packers that tobacco begins to deteriorate and to lose its richness of quality.

TOBACCO EXPERIMENTS CONDUCTED BY THE DIVISION OF SOILS IN COOPERATION WITH CONNECTICUT EXPERIMENT STATION.

The investigations of the Division of Soils and the comparison of certain types of soil in the Connecticut Valley with the tobacco soils of Sumatra, Cuba, and Florida, together with the fineness of the leaf produced on this soil in Connecticut, led to the belief that with the introduction of Sumatra seed and a change in the methods of cultivating, harvesting, and curing, a leaf of superior quality and usefulness could be produced. Of course, the climatic conditions of Connecticut, as compared with those of Sumatra, Cuba, and Florida, had to be considered, as climatic conditions play quite as important a part in the production of certain qualities in the leaf as do the soil conditions. That there is a difference in the climatic conditions of Connecticut, as compared with Sumatra, Cuba, and Florida, can not be denied. However, during the actual growing season the difference is slight, and it was believed that by the use of cheese-cloth shade, where the entire field is inclosed under cheese cloth, the difference in the climatic conditions could be overcome. With this conviction, the Division of Soils arranged with Dr. E. H. Jenkins, director of the Connecticut State experiment station, to make the experiment. The place selected was a plat of land owned by the Connecticut Tobacco Experiment Company, situated at Poquonock, and superintended by Mr. John A. Du Bon, who has conducted many experiments on this plat. The carrying out of the details and the general care of this new experiment was placed in the hands of Mr. Du Bon, the Division of Soils giving instructions as to how the shade should be constructed, the width of the rows (3 feet 3 inches), and the distance to be given the plants in the drill (12 inches). With these general instructions, Mr. Du Bon was able to fully carry out the line of work desired.

One-third of an acre was put under cover and one-half of it planted

in Connecticut-Havana seed and the other half in Sumatra seed. The first observation was that the plants thrived much better when transplanted under this shade and that their growth was much less interfered with than when set in the open field, the growth being rapid and continuous from the time they were well rooted until they reached maturity, at no time being checked by cool nights, as is often the case when the plants are not shaded. The cutworms of course got in their work as well under the shade as they do in the open field, but all the other worms, bugs, and insects that yearly do so much damage were excluded and gave no trouble. The high winds that lash and injure the leaves of the plants and cover them with sand in the open field did not in the least disturb the tobacco under cover. The hardest windstorms only caused a slight ripple of the leaves protected by this covering, so practically every leaf was sound and perfect. It was also observed that under the shade a higher and more even temperature was maintained, the atmosphere being at all times quite humid.

The plants grew to a height of 8 or 9 feet and matured from 24 to 36 leaves to the stalk. The fertilization and preparation of the soil was exactly the same as for the open part of the same field. The cultivation was practically the same, but the plants in the open field attained a height of only 4 or 5 feet. About the middle of the growing season this particular section experienced quite a severe drought, which checked to a marked degree the plants in the open field, but did not in the slightest degree deter the growth of the plants under cover. One-half of the plants of each type was topped and the other half allowed to go to bloom. While only the seed buds were taken off of the plants topped and all of the leaves left, still it is the opinion of Superintendent Du Bon and the writer that the stalks allowed to go to bloom produced the most desirable leaf. Of course, under different conditions the reverse might be the case, but this can only be determined by the general appearance of the plants. If the soil is sufficiently strong to develop the entire plant, it should not be topped; but if the plant shows sign of failing, the stalk should be topped, leaving only the number of leaves that the plant and conditions indicate can be developed.

The method of harvesting this crop was the single-leaf process, that is, the leaves were primed or picked from the stalk as they ripened. This is a part of the work that is of great importance. There is a stage of ripeness at which the leaves should be taken off in order to secure the best results, but we found it difficult to determine when the leaves had arrived at that particular stage. The result was that the leaves first primed were decidedly overripe; the leaves of the second priming had also stood too long; the third priming happened to be at just the right time and the leaf was absolutely perfect. All the other primings were made before the leaves were sufficiently ripe. At each priming 3 or 4 leaves were taken from each stalk. A

few stalks were topped low, leaving about 18 leaves. These stalks were allowed to mature. The stalks were cut and the tobacco cured on the stalk in the usual way. The leaves were coarse and uneven in color and were not nearly so desirable as the primed leaves. While the experiment as a whole was considered a great success, we know that a decided mistake was made in judging when the tobacco was ripe, a part being allowed to become overripe, while a good part was harvested underripe. It is easy to tell when tobacco that is grown in the open field is ripe, but the appearance of the leaf grown under shade is so entirely different that it was necessary to take chances. However, the experiment of last year will assist us in our coming experiments, and while other mistakes will no doubt be made we will certainly be able to judge more correctly of the ripeness of the leaf.

As the leaves were primed or plucked from the stalks they were placed in baskets and transported to the curing shed, where they were strung on strings. For this purpose a large, straight needle is used, and from 35 to 40 leaves are placed on each string, according to the size of the leaves. They are then evenly distributed along the string, leaving a space of about three-fourths of an inch between each leaf. The ends of the string are tied to each end of the ordinary tobacco stick and placed on the tiers in the ordinary way. The barn in which this tobacco was cured was partly filled with tobacco being cured in the ordinary way on the stalk. This tobacco had been harvested about ten days before we begun the harvesting by the new process of this experimental crop. It was therefore impossible to manipulate the barn just to suit this special tobacco, as the requirements of the one crop were often the reverse of the needs of the other. Even under these circumstances the curing was quite successful. When the tobacco was thoroughly cured it was taken down, the strings broken at each end, the leaves pushed to the middle of the string, and the string then wrapped around the head, forming a tie. After this it was packed in paper bundles of from 30 to 40 pounds, just as is ordinarily done with the other tobacco grown in that section.

The gross weight of the tobacco grown on this one-third of an acre plat was 700 pounds. It is reasonable to figure that the Connecticut-Havana seed leaf yielded a greater number of pounds than the Sumatra. Therefore, if the entire plat had been planted in Sumatra, no doubt the yield in pounds would have been less, while the value of the crop would have been increased, as the Sumatra type was decidedly superior in appearance and wrapping capacity. The size of the Sumatra leaf ran from 12 to 18 inches, while the Connecticut-Havana seed leaf was from 18 to 30 inches in length. The size of the Sumatra leaf is one of its points of merit. The leaves, from 12 to 14 inches, furnish a wrapper from each side of the leaf, and the 16-inch and 18-inch sizes yield two wrappers from each side, leaving in both cases but little waste or cuttings. The large leaf of the Connecticut-Havana will not

yield more than two desirable wrappers to the side, thus leaving a large percentage of the leaf near the midrib and butt of the leaf that goes to cuttings which are only suited for export trade. That means that it has but little value. Therefore the Connecticut-Havana will never be an economical wrapper leaf unless the size can be reduced.

After getting this tobacco into bundles, the next step was to carry it through the process of fermentation, which is necessary to even the colors and bring out whatever quality there may be in the leaf. Having only 700 pounds of this tobacco, it was necessary to put it in bulk with tobacco grown in the open field in the ordinary way, as the process of the bulk fermentation can not be successfully carried on with less than from 3,000 to 5,000 pounds in the bulk. With these different types and grades of leaf, it was exceedingly hard, in fact impossible, to give to each just the amount of fermentation it needed; consequently the endeavor was to so ferment the bulk as to get the best possible general average. The result was that while some classes and grades of the leaf were sufficiently cured, other portions would have been improved by further fermentation; but this could not be avoided with the mixed grades. To successfully ferment tobacco, it is absolutely necessary that each bulk should contain but one type or grade of leaf.

The fermenting of the experimental crop was done in Superintendent Du Bon's packing house at Poquonock. This packing house Mr. Du Bon has fitted up in the most improved way, and it is so arranged that by means of steam pipes running the entire length of the building an even temperature can be steadily maintained at whatever degree may be desired. As the heat from the steam pipes tends to dry the air and cause the tobacco to dry out, barrels half filled with water were placed in each room, and steam pipes put in so that live steam could be turned in the barrels. This would sufficiently heat the water to cause quite an amount of the moist steam to rise from the barrels, and any required amount of humidity could thus be secured.

In one of these rooms the bulk was put down, the size of the bulk being about 12 feet long, 5 feet wide, and 6 feet high. When bulked for the first time it was allowed to remain for about six days, at which time the bulk had reached a temperature of about 120°. The bulk was then turned or repiled. In doing this, four cases of tobacco were taken from the top of the bulk and set to one side; then the foundation of the new bulk was begun and continued until about half of the old bulk had been put on the new; the four cases first taken from the top of the old bulk were then put on the new one; the four cases were again filled with tobacco from the center of the old bulk and set aside. Again, we proceeded to take the tobacco from the old bulk and put it on the new until the old bulk was entirely removed. The four cases taken from the center of the old bulk were

then put on the top, and what had been the bottom and top of the old bulk became the center of the new bulk. In this way a very uniform curing was given the entire bulk. This bulk was allowed to remain for about twelve days, at which time the temperature had again risen to about 120°. The bulk was again turned, the same method being adopted as in the first turning. In this bulk the tobacco was allowed to remain for about fifteen days, during which time the temperature rose to about 115° and then gradually went down to about 100°, this rise and gradual fall of temperature being due to the fact that the heat had forced out the moisture and excessive gum. While portions of the tobacco would have been improved by remaining in bulk longer, quite a portion was sufficiently fermented. During the entire time the tobacco was in bulk the room was kept at a temperature of from 75° to 80°, and from time to time steam was turned into the water barrels as it became necessary to moisten the air.

At each turning of the bulk the tobacco was well shaken out, during which time the air in the room was kept sufficiently hot and moist to prevent the chilling and drying out of the tobacco. When it was determined that the most desirable part of the tobacco had been sufficiently cured the bulk was taken down and the various grades separated and packed in the ordinary seed cases. While this work of packing the tobacco was being done, Mr. J. C. Mitchelson, of the firm of Mitchelson & Hibbard, of Kansas City, Mo., was present and examined carefully the entire lot that was grown under shade, and he expressed a desire to buy it. As Dr. Jenkins, director of the experiment station, had placed the selling of this tobacco in the hands of Messrs. L. B. Hass & Co., of Hartford, Conn., Superintendent Du Bon advised Mr. Mitchelson to call to see the Messrs. Hass. This he did, and bought the entire lot of shaded tobacco at 71 cents per pound. Though this tobacco was reported by Mr. Du Bon as weighing, when first taken from the curing shed, 700 pounds, after fermentation the lot weighed only 577 pounds. This difference of 127 pounds is, however, not entirely due to shrinkage in the process of fermentation. A good many samples of this tobacco were taken away by the many visitors who came from time to time during the process of its curing and fermentation.

Knowing that the commercial value of this experiment could only be determined by submitting samples of the product to the leading packers of cigar leaf tobacco, getting them to examine it carefully, and then send samples over the country to leading manufacturers of cigars, the director of the experiment station withdrew from the sale about 100 pounds of tobacco, which was divided into lots of from 10 to 15 pounds and sent out to various dealers. These dealers examined the leaf carefully and then sent small samples to leading manufacturers, where the final test as to its merits as a cigar wrapper

leaf was made. These samples consisted of both types—Connecticut-Havana seed leaf and Sumatra. In every case the Connecticut-Havana was pronounced by both packers and manufacturers to be the finest and most useful domestic wrapper leaf they had ever seen. The Sumatra leaf was pronounced to be, however, far superior to the Connecticut-Havana and quite equal in every way to the finest leaf imported from the island of Sumatra. This was the verdict of the leading packers, dealers, and manufacturers of this country, and was not merely the opinion of those engaged in the experimental work. It is therefore only just and proper that the experiment should be regarded as a success.

The financial success of the experiment was never taken into account, the sole purpose being to determine whether such a leaf could be produced on this particular type of soil in the Connecticut Valley. That has now been clearly proven, but the commercial feature is yet to be worked out. This can not be done on a third of an acre, but a plot of several acres must be tried before the profitableness of the method can be determined. This necessary experiment must be made either by one or by a number of the leading packers of Connecticut tobacco, or by farmers of sufficient capital to stand the loss of a good percentage of the outlay in case such a loss should be the result of the experiment. It will be the work of the Department of Agriculture, as it will no doubt also be of the director of the Connecticut experiment station, to assist so far as possible any who see fit to undertake this experiment on a sufficiently large scale to demonstrate its commercial practicability.

The Division of Soils has kept no account of the money spent on this experiment, that part being cared for by the Connecticut experiment station. The cultivation and general care of a crop growing under shade is no more expensive than the cultivation and care of a crop growing in the open field. In fact, if there is a difference in the cost of this work, it favors the shaded field, for the reason that there are no worms to be picked off, as is the case with tobacco grown in the open field.

The only enemy that has attacked the tobacco under shade so far is the cutworm, which does its work immediately after the tobacco has been transplanted. The horn worm and bud worm, which do the greatest damage to the tobacco grown in the open field, are never seen on the tobacco that is protected by the cheese-cloth covering. Therefore it is reasonable and legitimate to conclude that the care of the plants during the growing season costs less under shade than it does in the open field. The new method of harvesting, taking the leaves from the stalk as they ripen, is of course more expensive than the old way of cutting the entire stalk. The difference in the cost is slight and will certainly not exceed 1 cent per pound on the cured tobacco. This difference in the harvesting is in a great measure, if

not entirely, regained in the future care and handling of the tobacco. In the first place, the leaves taken from the stalk will cure in about half the time required when cured on the stalk; secondly, when the tobacco is ready to be taken from the curing shed the work can be done much more rapidly, the work being simply to loosen the strings from the sticks, push the tobacco to the middle of the string, and use the string as a tie. The priming of the leaves from the stalk as they ripen greatly simplifies the work of assorting and grading. The first priming takes off, say, the first four bottom leaves of the stalk, the second priming takes off the next four leaves, and so on until all the leaves are off. Now, if each of these primings is kept separate, which is quite easy to do, the work of assorting and grading the leaf is greatly simplified and can be done much more thoroughly than is done by the ordinary help when all the leaves from the bottom to the top of the stalk are mixed. The foregoing statements show that the cultivation, general care, and harvesting of the tobacco grown under shade is not more expensive than the same work in the open field.

The only additional expense, therefore, would be the erection of the shades. What this would cost per acre would of course depend upon the cost of the material and labor in that special locality where the shade is to be erected. The material required for 1 acre is as follows:

Lumber:		
200 posts, 3 by 3 inches by 12 feet	feet	1,800
170 stringers, $1\frac{1}{4}$ by 4 inches by 24 feet	do	1,700
340 braces, 1 by 4 inches by 5 feet	do	666
54 stakes, 4 by 4 inches by 5 feet	do	288
		4,454
Wire:		
Guys, 54 pieces, No. 12, 16 feet long, 864 feet	pounds	23
Cloth supports, 18 pieces, No. 14, 212 feet long, 3,816 feet	do	65
Top braces, 8 pieces, No. 12, 212 feet long, 1,696 feet	do	46
Top fastenings, 18 pieces, No. 14, 212 feet long, 3,816 feet	do	65
		199
Wire staples:		
$1\frac{1}{4}$ inch	pounds	3
[illegible] inch	do	4
		7
Nails:		
12d. cut	pounds	22
8d. cut	do	16
4d. wire	do	5
		43

Cheese cloth to cover 1 acre, including walls, would be about 5,764 yards. This goods can be bought at present at $1\frac{3}{4}$ cents per yard in 36-inch width, or it can be purchased in 144-inch width at $7\frac{3}{8}$ cents per running yard. The 144-inch width is far more desirable, as this width goods can be put on the frame and tacked to the stringers, covering

the 12-foot space between the posts. There is a slight difference in the cost of the 144-inch goods as compared with the 36-inch goods, but the wider goods will be considerably cheaper than buying the narrow and sewing it together. With this information anyone can figure what the cost will be to cover an acre. The frame should last for at least five years, while it would hardly be reasonable to expect the cheese cloth to last more than one season. It would therefore be proper to figure against the first crop the entire cost of the cloth and one-fifth of the cost of the framework.

While the only sections where it would be wise to undertake the production of this special type of leaf, as far as is known to the Division of Soils, are on certain soils in the Connecticut Valley and in certain parts of Florida, yet there may be other sections having this special type of soil where the leaf could be produced quite as successfully. The work of the Division in its soil surveys will greatly assist in settling this question, as this work takes carefully into account both the soil and climatic conditions. When these are thoroughly understood it is far easier to determine what may be expected.

The soil survey of Lancaster County, Pa., made by this Division led to the belief that in the area surveyed it would be unwise to try to grow the Sumatra type of leaf there. It is, however, believed that a filler leaf of far superior quality and value could be produced in Lancaster County by the introduction of new seed and by certain changes in the methods of cultivation, harvesting, and curing. To this end, the Division of Soils has arranged with some of the most successful planters to conduct experiments with them during the present year and several acres will be planted. Of course, we have no absolute assurance of success, but it is reasonable to believe that great improvement over the leaf now being produced in that section can and will be made.

Eor several reasons the tobacco produced in Lancaster County brings about the lowest price to the farmer of any cigar type grown in this country. The first reason is that the bulk of the leaf produced is large and coarse and can not be used for wrapper purposes, with the possible exception of a very small percentage that might be used for cheroot and stogie wrappers. The enormous size of the leaf makes it decidedly undesirable for filler purposes, regardless of what quality it might possess. The next great trouble is the wonderful amount of loss sustained by the packer from what is known as black rot. Just when and where this black rot originates is a question yet to be solved. The most reasonable conclusion is that the trouble begins while the tobacco is hanging in the farmer's curing shed, and is developed and brought out in the process of case fermentation. The Division is now at work trying to locate and remedy this trouble.

The present method of packing and fermenting the Pennsylvania tobacco, which is the same as practiced by all the Northern States that produce cigar leaf, will be briefly described:

When the tobacco is delivered to the packer by the farmer it is at once graded, tied in hands, and packed in cases, being put into these cases under pressure. When the case is filled and closed it is stored and remains without any attention for eight or ten months, the idea being that the tobacco will warm up at the beginning of spring weather and continue to ferment during the entire summer. In the early fall, for the first time after being packed, this tobacco is examined and sampled. The result is that this examination, in many cases, reveals the fact that a large percentage of the tobacco has become damaged, or, as the packers say, has developed black rot. Then the work of opening up all the cases, picking out the hands or leaves that show black rot, and repacking the sound portion becomes necessary. This involves a great deal of expense and labor, to say nothing of the loss of the tobacco that is damaged.

It was claimed by many of the packers that the damage occurs soon after the tobacco was packed and while lying in a chilled condition. It was believed that this could be overcome by what is known as forced sweating. Many of the packers therefore prepared a room in their warehouses where, either by means of steam or stoves, the temperature could be kept steadily at from 110° to 120°. As soon as the case of tobacco is packed it is put into this room, and this is continued until the room is well filled. It is then tightly closed and the temperature, as before stated, is kept at from 110° to 120°. This sweating process is kept up from thirty to forty days, at the end of which time the tobacco is taken out. While there is some show of curing in the center of the case, the tobacco at the bottom and on the top and sides of the case is not cured, but has become exceeding dry and the dreaded black rot shows as prominently as ever. This experiment has proved far from satisfactory.

In October, 1900, the Division of Soils began experiments in the fermentation of the Pennsylvania tobacco. The experiments have been conducted at Lancaster, the first tobacco fermented being a lot of the 1898 crop. This tobacco although two years old, was absolutely raw (unfermented). The owner of this lot of tobacco, Mr. Menno Frye, is one of the leading packers of Lancaster and has one of the best appointed warehouses in that section. He was engaged at the time in trying to sweat this lot of tobacco by the method most approved in that locality at the time. The method was as follows:

The tobacco was taken from the cases and the hands well shaken to get the leaves separated. The heads of the hands were dipped in warm water to a depth of about 4 inches and placed with the heads down in a screen-bottomed vat or trough, the object being to allow the water to drip off. The vat is sufficiently large to hold in this manner one case of tobacco. When filled the tobacco was well covered with damp blankets and put into a small tight room, where the temperature was kept at about 120°. Here it was allowed to remain for three or four hours, by which time the leaves are thoroughly soft

and pliable. The tobacco was then taken from the vat, heavily packed in cases, and stored in a room such as described with a temperature of from 110° to 120°. This room was kept closed and the tobacco allowed to remain in it for about thirty days, at the end of which it was found that while the tobacco in the center of the case had cured considerably, the tobacco near the top, the bottom, and the sides of the case had not cured, but had dried out and a large percentage was damaged by black rot.

After stating carefully our plan of fermenting this type of tobacco, Mr. Frye kindly offered us space in his warehouse and the tobacco necessary to conduct the experiment. We began with the same lot of 1898 tobacco. We took this tobacco from the old cases, shook it out well, and dipped the heads of the hands into warm water, allowing them to be immersed 4 inches. The hands were again shaken out, thus distributing the water thoroughly through the hands or bundles. The tobacco was then placed loosely in cases and allowed to remain for twenty-four hours, by which time the tobacco had thoroughly taken up the water, making the leaves soft and pliable. When about 8,000 pounds were prepared in this manner we began bulking it, the bulk being 6 feet wide, 12 feet long, and 6 feet high. The tobacco was not packed, but simply piled loose, only hand pressure being used for this bulk, which was made in a room where the temperature was kept at about 75°. Twenty-four hours after the bulk was completed the temperature of the center had reached 100°, and in three days the temperature was 135°, at which time the bulk was repiled, care being taken to get the tobacco of the sides, the bottom, and the top of the old bulk in the center of the new one, which remained undisturbed for about six days. When the temperature had risen to about 135° it was again repiled and allowed to stand for fifteen days, at the end of which time the tobacco was thoroughly cured, dried out, and ready for packing, without the least sign of black rot.

Mr. Frye was so well pleased with this result that he asked that we continue the experiment until all the 1898 tobacco was fermented. This we did, the result being that the entire lot of 38,000 pounds was thoroughly cured without the slightest showing of damage or black rot. As the new crop was about ready for the buyer at this time, Mr. Frye bought a few crops for immediate delivery, in order that our work might be continued, calculating that if our method proved as successful with the new crop as it had with the old he would equip his entire plant for handling tobacco in this way.

The first lot of 1900 crop delivered to Mr. Frye by the farmers was apparently quite dry. However, we proceeded to put it into bulk, bearing in mind that it is always risky to apply water to new tobacco. After waiting for two or three days the bulk had not warmed up, and being anxious to hurry this experiment, and in view of the fact that all the old tobacco had stood the treatment so well, we allowed

ourselves to make the error of applying water to this lot and rebulked it. For six or eight days all went well and we were congratulating ourselves that after all the application of water was not a mistake, when we discovered small evidences of black rot. In spite of all we could do, this trouble spread rapidly and the result was that about 40 per cent of the bulk was lost or badly damaged. Fortunately, this blunder on our part did not in the slightest discourage Mr. Frye or cause him to lose faith in the method. We continued the work of bulking the new crop as fast as received from the planters, but did not apply any more water. The bulks were slow in warming up, but after a rise in temperature began it rose rapidly, and while the tobacco appeared exceedingly dry when first received from the farmer, it showed evidences of containing much moisture as soon as the temperature rose. We found that it was unnecessary to repile these bulks very often, and we allowed the first bulk to remain from fifteen to eighteen days, by which time a temperature of from 125° to 130° was reached. The bulk was then repiled and allowed to remain for about twenty days, during which time the temperature rose to about the same height and fell to about 100°. At this stage Mr. Frye pronounced the leaf sufficiently cured for packing.

This method of fermentation is also being conducted by Mr. S. N. Root, of Landisville, Pa. Mr. Frye and Mr. Root have both fermented several hundred thousand pounds by this method and are greatly pleased with the results, the only loss being the bulk first mentioned of the 1900 crop. In addition to the Pennsylvania leaf, Mr. Frye allowed us to ferment for him several carloads of Connecticut leaf, all of which cured entirely to his satisfaction.

While these experiments were being conducted in the private warehouses of Mr. Frye at Lancaster and Mr. Root at Landisville, all packers interested in the method were invited to call from time to time and examine the work. Many packers visited the warehouses, and the result is that Mr. Zook, agent for E. Rosenwald & Bro., and Captain Wilcox, agent for G. Falk & Bro., have equipped their large warehouses for handling and fermenting their packings in this way. Captain Wilcox has now in bulk several carloads of Connecticut-Havana seed leaf, all of which is curing entirely to his satisfaction. Mr. Zook has quite a quantity now in bulk, but it has not advanced sufficiently in curing to criticise. However, Mr. Zook watched carefully the tobacco cured in Mr. Frye's warehouse and expressed his belief that this method would in a short while be adopted by all the packers, it being, in his judgment, far superior to the old method.

While we feel encouraged with the work we have done, it yet remains to be seen how this tobacco will keep after being packed in cases. If the germs of black rot are taken on while the tobacco is hanging in the curing shed, which we believe to be the case, it is still possible that later on this trouble will develop. If this should occur it would not prove that our method of fermentation is incorrect, but would

prove that black rot is a disease that exists previous to the fermentation, and probably had its origin in the farmer's curing shed. We know from actual experiment that sound tobacco of other sections, thoroughly cured by this method, will keep in good condition for years.

In conducting experiments in Pennsylvania during the present year of 1901 we propose to give special attention to the harvesting and barn curing, which we shall watch closely. After this we will be better able to determine just where black rot has its origin. The Department expects to extend this line of work into the States of Ohio and Wisconsin, where the packers experience the same trouble as do the packers of the Pennsylvania leaf. The Zimmer Spanish, grown in Ohio, is one of the most acceptable fillers of this country, and after being fermented, classified, and packed it sells to the manufacturers at a fair price, but the farmers realize a very low price. This is largely due to the fact that the packers experience such a tremendous loss from black rot and other causes. While this loss may be partly due to the present method of fermenting and packing, it is more probably caused by improper management on the part of the farmer during harvesting and curing. This is also true of the seed-leaf of Wisconsin, which is unquestionably the best binder-leaf produced in this country. Since the packers are forced to figure that a large percentage of their purchase will be lost by black rot and other diseases, they must buy from the farmers at a low price in order to stand the loss, pay for the great amount of labor necessary to clean the tobacco, get it on the market in a sound merchantable condition, and sell at a reasonable profit. It is the belief of the Department of Agriculture that the origin of this disease can be located and remedied.

Whether the Department will experiment in these States with new varieties of tobacco or not can not be determined until a survey of the soils is made. If the work should indicate that it is possible to produce other types of leaf of better quality and value, experiments will be conducted along that line; if not, then it is the purpose of the Department to try to improve the quality of the varieties now being produced.

The crops that have been grown in the State of Texas from Cuban seed indicate that a leaf of excellent quality can be produced from this seed. The leaf grown in Texas has never been properly fermented and has been placed on the market uncured, in consequence of which it has not found favor with the manufacturers. As early as possible the Department will take up this work in Texas, when experiment will be made in growing and fermenting Cuban tobacco in this State.

No special plan has yet been formulated for work in the States producing the heavier types of tobacco, such as are used in snuff, smoking, and plug manufacturing. Attention will, however, be given to these tobaccos as early as possible.

LIST OF MAPS.

Owing to a fire in the establishment of the lithographers to whom the contract was awarded for furnishing the maps to accompany this report, most of the original drawings were injured and some of them were destroyed. Fortunately the work had progressed so far that either the lithographic stones or the proofs were available for the reproduction of the entire set of maps, though with some delay. The loss of the original copy made it difficult to read the proof of the maps, and necessitated in some cases a comparison with the original field records. Every care has been taken in reading the proof, and it is believed the maps are accurate. It is possible, however, that some errors have been overlooked, although this is not probable.—M. W.

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